ESD ARRANGEMENTS & LINKED SHIP/ SHORE SYSTEMS FOR LIQUEFIED GAS CARRIERS

SIGTTO

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Witherby Seamanship International Ltd
4 Dunlop Square, Livingston
Edinburgh, EH54 8SB
Scotland, UK

Tel No: +44(0)1506 463 227
Fax No: +44(0)1506 468 999

Email: info@emailws.com
www.witherbyseamanship.com

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SIGTTO has produced this guidance note due to members' concerns about the different interpretations of the functional requirements for ESD systems, particularly those differences between the needs of the LNG industry and those of the LPG industry and how these may interact with linked ship/shore shutdown systems. This document is also intended to promote and encourage more widespread use of linked ESD systems at both LNG and LPG terminals, particularly where cargo transfer rates are high or where the cargo being handled is one of the products referred to in Chapter 17 of the 1993 edition of the IGC Code. It is not the intention of this document to contradict any national or international standards or requirements for operational practices at the liquefied gas ship/shore interface.

Some of the problems currently experienced are caused by an inadequate understanding of the basic philosophy of the systems coupled with the ability of new technology, notably PLCs, that facilitate change of functionality without changing the hardware. This is compounded by changes in operation and design of LNG carriers, particularly with regard to gas burning in port and reliquefaction. The IGC Code originates from the mid 1970s and reflects the operational practices and regulatory approach of those times. Therefore, it is not surprising that differing interpretations should arise after 30 years.

Furthermore, the expansion within the liquefied gas industry has introduced new operators with new ideas. It is important that the lessons learned in the past are passed on clearly.

This document is not intended to provide a detailed technical specification for the design of ESD systems, but sets out the functional requirements such that a skilled design team can produce a detailed specification.

The sections are titled as follows:

Part 1: Philosophy and General Requirements.

Part 2: ESD Functions and Associated Systems

Part 3: Linked ESD Systems

Part 4: Appendices

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PART 1 – PHILOSOPHY & GENERAL REQUIREMENTS

1 Introduction

The functions of the cargo Emergency Shutdown (ESD) system are to stop cargo liquid and vapour flow in the event of an emergency and to bring the cargo handling system to a safe, static condition.

The current edition of the IGC Code [1][1] lays down core requirements for an ESD system. These comprise manual trip points and automatic fire sensors that can initiate remote closure of *emergency shutdown valves* "for shutting down liquid and vapour cargo transfer between ship and shore" and require that this emergency trip, when activated, must also stop cargo pumps and compressors. However, these provisions do not necessarily provide adequate protection, particularly against overflow, during other operations involving the transfer of liquid and vapour on board. It must be recognised that operations such as reliquefaction or cargo tank spraying may be routine operations at sea. These deficiencies will be addressed in the new updated IGC Code and are described in this document.

The IGC Code has no jurisdiction over activation of ESD systems at shore installations, but it is recommended that linked systems are installed such that activation of an ESD trip on the ship will send an ESD signal to shore and vice versa.

However, it is important to remember that the scope of the IGC Code effectively ends at the ship's manifold and it has no mandate over the design of the terminal's equipment. Although the Code requires cargo transfer procedures to be agreed and loading rates to be adjusted to limit surge pressures on valve closure, the impact of shipboard emergency shutdown on the shore is not otherwise covered.

The legal framework of the IGC Code means that its language is necessarily prescriptive but, with little or no explanation to the reasoning behind its statements, problems with interpretation sometimes occur. One area where opinion has sometimes been divided is in LNG carriers, where gas burning is normally carried out concurrently with cargo loading. However, a solution to this problem is discussed in Part 2 of this document.

The relevant paragraphs from the 1993 IGC Code together with explanatory notes are included in Appendix A. This is intended to help clarify the areas of the IGC relating to ESD that are seen as unclear.

The core requirement of the IGC Code are that an ESD shutdown is initiated by manual trips or by thermal devices. However, there may be valid reasons to supplement these core initiators with others to suit actual operating requirements. Similarly, in some cases additional shutdown actions may be necessary to stop liquid and vapour flow. As well as these ESD functions, the Code requires trips designed to protect the ship and its cargo system against damage. As these trips often require one or more cargo pumps or compressors to be stopped, in many ships the actions are combined such that a trip due, say, to low tank pressure, will be activated via the ESD system or vice versa.

There are, therefore, differences between the core ESD trips defined by the IGC Code that are common to all gas carriers and those that may be in place on a particular vessel. Although this distinction may not be of great consequence when the vessel is at sea, it could be important when considering cargo operations in port, particularly when the ship's ESD system is linked to the terminal's system.

For the purposes of this document, the acronym 'ESD-1' will be used when referring to the emergency shutdown of the transfer of cargo during loading or unloading. Depending on the context, the term may apply to an ESD-1 trip signal, event or condition. Readers should be aware that although the term 'ESD-1' is used by many operators and is found in several guideline documents, it is not universally recognised throughout the industry. SIGTTO use it here only to provide a clear distinction between the various trip functions within the overall cargo ESD system. Other cargo system trips required by the Code will be discussed in Part 2.

During transfer, stopping the flow requires the pumps and compressors or blowers to trip and, isolating the ship and shore from each other, requires the intervening valves to close.

There have been a number of well-publicised instances where wind has blown a gas carrier off the berth while still connected to the loading arms. Ship break-out must therefore be seen as a credible event and both the LPG and the LNG industries are under obligation to do all that they can to mitigate the risk of escalation to a major incident.

The cargo transfer emergency shutdown process at the majority of terminals where these systems are implemented is divided into two stages:

1st stage – shuts down the cargo transfer process in a controlled manner ('ESD-1')

2nd stage – activates the Emergency Release System installed on transfer arms ('ESD-2')

[1] Square brackets denote reference documents listed on page 11.

This second stage function is primarily to protect the transfer arms and ship's manifold should the vessel drift out of a pre-determined operating envelope, which will typically be detected by sensors on the transfer arms. Emergency release may also be manually initiated from ashore but it is not designed to be initiated from the ship. The emergency release system is designed to be an entirely independent and separate function and its operation is not dependant on the presence of a linked ESD system. As such it is outside the scope of this document and no attempt will, therefore, be made to cover the subject in anything other than general terms (see Part 2).

The IGC Code requires all gas carriers to have an ESD system and so it must be recognised by terminals that the ship may shut down automatically, without prior warning, during cargo transfer operations. It is, therefore, essential that the terminal understands the implications of this, particularly with respect to the generation of surge pressures in the transfer system.

If investigations reveal that, under normal and emergency operating conditions, the risk of damage by surge is judged by all parties to be tolerable, then transfer with an unlinked shutdown system could be considered acceptable. Operators should be aware that changes to plant design or to operating procedures may invalidate the original studies that led to the decision not to fit a linked system. A formal review should be performed if changes have taken place.

The LNG industry has recognised the safety benefits of adopting linked ship/shore shutdown systems but currently it is not as widely adopted in the LPG trade. SIGTTO recommends that any LNG, LPG or chemical gas ship that does not have the ability to link its ESD system to shore is modified to make this possible. Similarly, any new terminal handling the bulk transfer of these cargoes or such terminals that are undergoing major refurbishment should be fitted with linked ESD systems.

The primary concept of a linked ESD system is that the party receiving liquefied gas, ie the ship in the loading port and the shore in the discharge port, can shut down the transfer process in a safe and controlled manner and so remain in control of events at its location. The receiving party should never arrive at the situation where the only option is to shut valves against the incoming full flow of liquid. Furthermore, should any failure leading to leakage or fire be discovered, either party may initiate a controlled shutdown of the transfer process without risk of exacerbating the situation by the generation of unacceptable surge pressures anywhere in the pipework on ship or on shore.

2 Definitions, Terms and Abbreviations

For the purposes of this document the following abbreviations shall apply:

ESD	*emergency shutdown*
ESD-1	*emergency shutdown stage 1* – shuts down the cargo transfer operation in a quick controlled manner by closing the shutdown valves and stopping the transfer pumps and other relevant equipment in ship and shore systems.
ESD-2	*emergency shutdown stage 2* – shuts down the transfer operation (ESD-1) and uncouples the loading arms after closure of both the ERS isolation valves.
MOV	*motor operated valve* – valves in the product transfer system capable of being operated remotely.
ERC	*emergency release coupling* – uses stored energy to ensure breakout through any ice build up, required to uncouple the loading arm after initiation of ESD-2 action. Synonymous with 'PERC' (*powered* emergency release coupling).
ERS	*emergency release system* – consisting of an ERC mechanically linked to two isolation valves, one upstream and one downstream of the coupler. Fitted in the outboard arm of a loading arm.
QCDC	*quick connect/disconnect coupler* – hydraulic clamping device at some terminals to connect loading arms to the ship's manifold flange in lieu of a bolted flange (NB. not part of ERS).
CTS	*custody transfer system* – comprising a primary level gauge and a system of accurate temperature and pressure sensors for fiscal measurement of the cargo in the ship's tanks under the terms of the Sales & Purchase Agreement. CTS equipment is subject to periodic verification of accuracy by independent bodies approved by the contractual parties and relevant Customs authorities.

HHL	*high-high level* – an alarm signal set above normal filling level.
MARVS	*maximum allowable relief valve setting*
RGB	*return gas blower* – used at an import terminal to return displaced vapour to the ship during discharge.
IAS	*integrated automation system* – the ship's integrated computer control & monitoring system that is installed on modern gas carriers. In the context of this document, the name is synonymous with 'distributed control system' or 'DCS' – a single fully integrated and dual redundant control system.
GCU	*gas combustor unit* or *thermal oxidizer* – a gas incineration unit, installed in LNG carriers with diesel or diesel-electric propulsion to allow disposal of excess gas in compliance with the IGC Code.
SSL	*ship shore link* – means of communicating shut-down signals, data and voice communications between ship and shore. May be by a simple pneumatic hose fibre optic, electric cable or radio telemetry.

Other terms used in the text are:

Ship/Shore Interface – all operations of the ship and shore relating to cargo transfer, access, mooring and communications.

Linked ESD system – transmits ESD signals from ship to shore or vice versa via a compatible system. Various technologies have been adopted, such as pneumatic, electric, fibre-optic and radio telemetry, but vessels trading worldwide may need more than one.

Unlinked ESD system – a basic system that only initiates a shut down in its own environment, ie on ship or on shore. This is the minimum system required by the IGC Code for ships but might leave the possibility of excessive pressure if the ship's manifold valves close during cargo transfer.

Pendant ESD system – in the context of this document, a hand held portable device provided either by the ship to the shore or by the shore to the ship for the manual tripping of its ESD system by the other party in the absence of a compatible linked ESD system.

Intrinsically safe (IS) system – an electrical system designated for use in hazardous areas and commonly used for control and monitoring circuits. It works on the principle that no spark or thermal effect within the system is capable of releasing sufficient electrical or thermal energy under normal or abnormal conditions to cause ignition of a flammable or combustible atmospheric mixture in its most easily ignitable concentration. Hazardous area classification and related electrical equipment specifications are governed by national and international standards or classification society rules.

Terms relating to shore equipment

Dry-break coupling – term sometimes used to denote an ERS where design leakage on release is minimal.

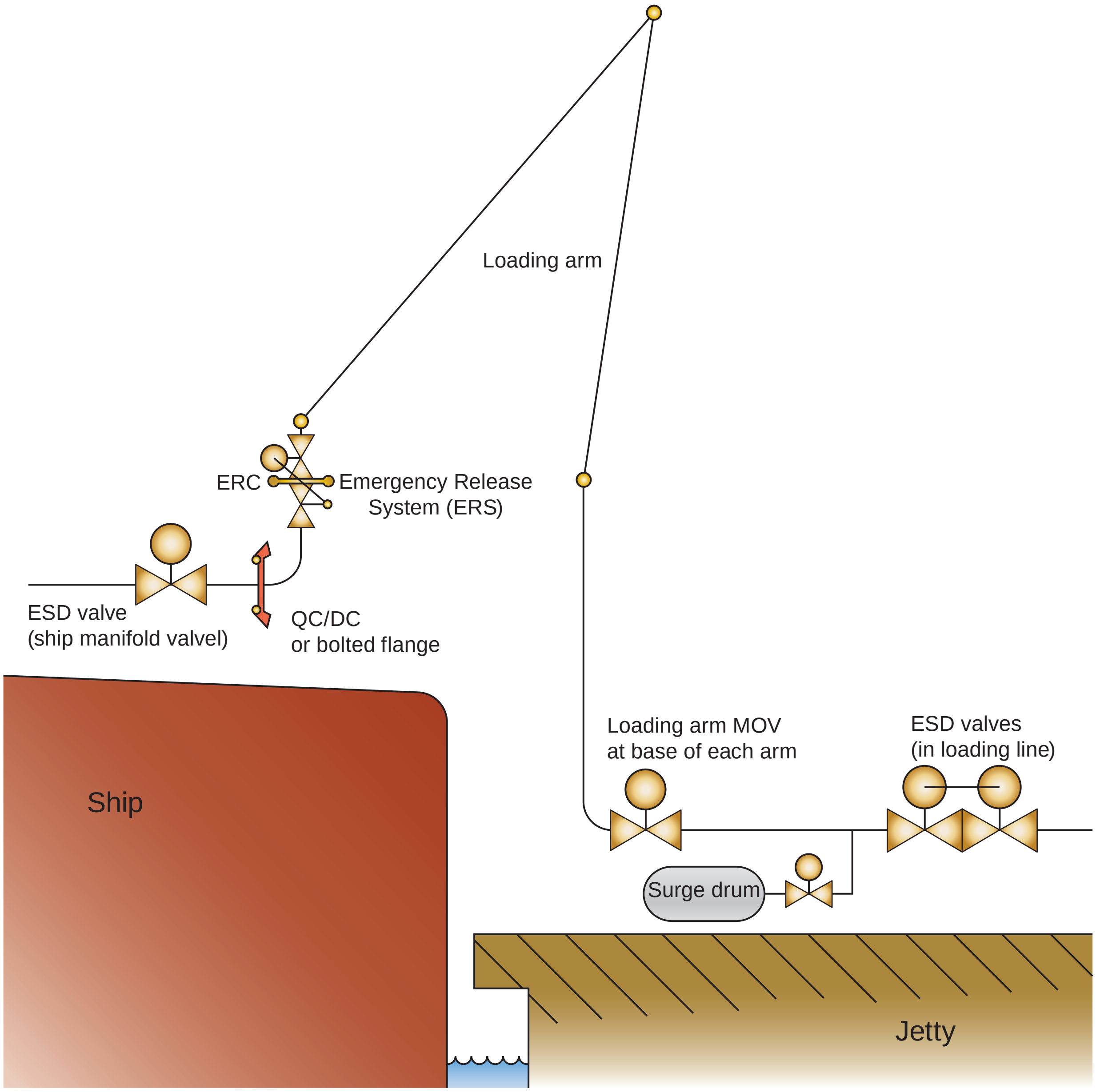
Loading arm or *marine transfer arm* – the articulated metal loading arm system, used for transferring products to or from ships with the capability of accommodating differences in tides and freeboard and ship motions. *Loading* arms are synonymous with *unloading* arms or *hard* arms and are used instead of hoses at all LNG terminals and at many LPG and chemical gas terminals.

Loading arm MOV – motor operated valve provided at the base of each loading arm for primary isolation of the loading arms from the liquid and vapour pipelines on the jetty.

Operating envelope – the maximum spatial area in which the presentation flange of a *marine transfer arm* can operate safely. Determination of this spatial envelope must be based on the range of the ship's manifold location due to changes in tides, freeboard, surge and sway.

Surge drum – a pressure vessel that may be installed in the shore side of the cargo transfer system to alleviate pressure surges generated by the operation of the ESD system.

Equipment at Typical Export Terminal Interface



Terms relating to ship equipment

Liquefied gas pumps

Transfer pump – the cargo pumps installed in the ship's tanks or the loading pumps installed in the shore tanks in an export terminal. It may also be a cargo booster pump in an LPG or chemical gas carrier.

Spray pump – low-capacity pump installed in some types of gas carrier. Although the specific function may vary, they are generally used for spray cooling to reduce cargo tank temperatures sufficiently to enable loading to proceed and are sometimes used for cooling pipelines or stripping cargo tanks before warm-up. In LNG carriers with steam turbine propulsion a spray pump is sometimes used for supplying LNG to a forcing vaporizer to provide additional boiler gas fuel.

Gas fuel pump – smaller version of a spray pump, optimised to supply LNG to a forcing vaporizer, to supplement natural boil gas being used as fuel for vessels with dual-fuel diesel engines.

Gas compressors

Vapour return compressor – gas compressor fitted on board the ship to return to shore the gas displaced during cargo loading. Also used to circulate the containment system during warm up. Peak demand will typically require the use of two compressors operating in parallel.

Gas fuel compressor – low-capacity compressor used to transfer boil off gas to the gas burning system in an LNG carrier. Although in the LNG trade, the ship's gas compressors are commonly known as *High Duty (HD) Compressors* or *Low Duty (LD) Compressors*. These names are deliberately not used in this document because *High* and *Low Duty* can infer that the two machines fulfil the same function and differ only in capacity.

Boil-off gas compressor or *BOG compressor* – although sometimes used as an alternative name for a gas fuel compressor, in this document it will denote a compressor the primary function of which is to transfer boil-off gas to the cryogenic heat exchanger of an onboard reliquefaction plant.

Reliquefaction system compressor – those gas compressors used within cargo reliquefaction systems.

Volumetric compressor – a reciprocating or other positive displacement compressor capable of producing excessively high discharge pressures if run against a shut valve.

Containment system and pipelines

Normal filling level – the approved loading level of the ship's cargo tanks.

Tank loading valves or *tank filling valves* – remote operated valves that control liquid gas flow to individual cargo tanks.

ESD valves – remote operated fail-closed tight shut-off valves that stop liquid flow between ship and shore on ESD-1 activation.

Gas burning systems in LNG carriers

Dual fuel system – a system designed to burn natural gas fuel or oil fuel alone or simultaneously. It may be a boiler, compression ignition engine or gas turbine.

Master gas fuel valve or *BOG master valve* – a remote operated fail-closed valve installed in the cargo area to isolate the cargo system from the spaces containing gas burning equipment.

Combustion control system – the system that controls the quantity of fuel and air supplied to the boilers of a steam-powered LNG carrier to ensure that the desired steam pressure is maintained under all conditions of steam demand and with acceptable combustion at sea, in port and while manoeuvring.

Burner management system – the logic system of a boiler and its interface with the oil and gas burners that ensures their safe operation.

3 Emergency Shutdown Systems

The main purpose of this document is to clarify the requirements for emergency shutdown relating to the ship/shore interface but, in doing so, it is also necessary to explain the relationship of other 'safety systems' covered by the IGC Code as there is a certain amount of overlap. Therefore, this document will cover:

- ESD-1
- cargo tank overflow protection
- cargo tank pressure protection
- gas burning safety system.

Note that ESD-1 does not necessarily include cargo tank vacuum protection. However, SIGTTO recommends consideration be given to a limited number of additional ESD-1 initiators, discussed in Part 2, Section 2.

It is a mandatory requirement that gas carriers be provided both with high level alarms and overfill protection, each system independent of the other. High level alarms must also be independent of other level indicators. In simple terms[2], the overfill protection system closes a valve to prevent the tank becoming liquid full. Although the IGC Code does not specify a particular level at which the high level alarm should operate, it is commonly set at a level that will warn the operator some

[2] The Code also requires the valve to be actuated "*in such a manner that will prevent excessive liquid pressure in the loading line*".

fifteen to twenty minutes before the target finishing level is reached while loading at full loading rate. Therefore, in a ship with a normal filling ratio of, say, 98%, the alarm would be set at around 95% tank volume.

To suit ship variations the IGC Code allows the use of either the designated "emergency shutdown valve" or "another valve" for overflow protection. Historically most overflows have occurred not during loading but during discharge. This fact needs to be taken into account when designing the system as it is possible to comply with the IGC Code yet not have a sufficient level of protection against an overflow caused, for example, by internal transfer.

Overflow protection is covered in more detail in Part 2, Section 3.

In addition to relief valves, pressure protection of the containment system is provided by a number of manual and automatic trips that shutdown cargo machinery. In some vessels, particularly those without a ship/shore link, the functions of ESD-1 and 'cargo tank protection' are combined and this is the source of yet more confusion. This subject is explained in Part 2, Section 4.

One area of the IGC Code where different interpretations arise concerns the gas fuel compressors in LNG carriers. When the Code was written in the 1970s, although gas burning in dual-fuel mode during loading and while manoeuvring had already become accepted practice, only a relatively small number of vessels were involved. Technical advances and environmental considerations mean that this is now common and gas burning systems have been accepted as complying with the philosophy of the IGC Code. However, the Code is interpreted by some as requiring this compressor to be tripped on ESD-1 without consideration of other factors. The main practical advantage of separating the gas fuel compressor from the ESD system is that a route is always available for the disposal of excess gas in the event of an ESD-1, rather than causing the cargo tank relief valves to lift. This is of particular significance during loading where the rate of cargo tank pressure rise can be particularly rapid. The alternatives are explained in Part 2, Section 5.

It is strongly recommended that extreme caution is used when considering further initiators beyond those described in Part 2. This is particularly relevant when considering in service modifications to software, such as may be undertaken when the vessel is on trials. Any such proposals should be subject to rigorous assessment, including a HAZID to ensure that they provide a real benefit and any modifications should be fully documented and 'as built' drawings provided.

It is essential that all personnel involved in cargo operations have an understanding of the functions of the ESD system at a depth relevant to their seniority. Consideration should be given to displaying a flow diagram in the cargo control room as a visual aid.

4 Ship/Shore Links

At the highest level, the purpose of the ship/shore link (SSL) is to transmit, without delay, a signal from one party to the other, ie ship to shore or vice versa. Various link technologies are currently used in the liquefied gas industry:

- Electric
- fibre-optic
- radio telemetry
- pneumatic.

The first three of these systems meet the high level technical requirement and, furthermore, have the capacity to transfer additional information such as telephone links, data for mooring tension monitoring systems etc. These latter attributes are recognised as valuable add-on benefits of linked systems but, since they are not the prime reason for the link, are not discussed further here beyond noting that the provision of these additional features should not jeopardise the primary function of the ESD link system. SIGTTO does not recommend any particular link technology, but provides in 'Part 3' the experiences of operators such that the reader can make an informed decision as to which system, or systems, would be most suitable for his particular installation. Furthermore, suggestions are given for pin configuration of connectors as these are a regular source of problems at the ship/shore interface.

It is also noted that the first generation linked systems were often based on pneumatic technology and many terminals have this facility as a back-up or secondary means of providing a shut-down link. While some small time lag is unavoidable with pneumatic links, they are simple and certainly better than no link in event of non-availability of the main system.

A fundamental principle of complex safety systems, such as the linked ESD system, is that all parts should be capable of being tested in a way that demonstrates positively the good functioning of the *total* system. Given the criticality of the ESD system it is also vital that it is regularly tested, both for the functionality of the link and for the initiators.

Pendant ESD units

During the development of the SIGTTO intrinsically-safe ship/shore link in 1987 it was recognised that the industry would need time to implement change and for the new equipment to be installed. Pendant units were therefore incorporated into the design, primarily to cover this interim period but also to provide a form of backup. Two types are available: one designed to be plugged into the Jetty Assembly, with the pendant box passed to an unequipped ship; the other for plugging into the pendant connection on the ship's junction box, with the pendant passed to the shore. Although these pendants allow shutdown by the opposite party, they rely on manual intervention and are not a substitute for a system that ensures simultaneous shutdown of ship and shore equipment.

Emergency operation of normally linked systems

The practice of linking ESD ship and shore systems is widespread in the LNG business because it demonstrably reduces risk, principally from that of generating excessive surge in the event of a unilateral shutdown. This implies that the linked system should be viewed as a critical safety system and so operations without a fully functioning linked system should be approached with extreme caution.

It is recognised that, despite testing procedures, circumstances may arise where the ESD link is not available. It is therefore recommended that the terminal and ship discuss contingency planning on how to proceed in these circumstances. Although pre-arrival testing will lessen the chances of a fault with the ship/shore link being discovered only after the ship has berthed, such occurrences are not unknown and contingency planning should cover this eventuality. While the most prudent course of action may be to delay transfer until a repair can be effected, berth scheduling, commercial constraints and tidal or weather conditions will all put limitations on the time available, so a decision may be made to proceed without a working ESD link.

The procedure to adopt in event of failure of the primary link system should be addressed as part of a terminal's emergency procedures. The following points are pertinent:

1. Provision of a back-up link system capable of providing, as a minimum, linked transfer of the ESD-1 signal. A pneumatic system is acceptable for this, see Part 3 Section 1.
2. The spare parts holding philosophy for the primary system should be reviewed to ensure that an appropriate level of spares is held to facilitate speedy repair and mitigate against common failures.
3. Notwithstanding the foregoing, it is recommended that each terminal performs a surge calculation on their specific pipeline arrangement to identify the maximum safe transfer rate as this information will be vital if the link system is not available. Without the results of such calculations it is not possible to assess the risks involved in unlinked operations.

Mitigation measures may also include:

- Making use of a Pendant ESD unit, if available
- reducing the loading or discharge rate
- increasing the number of personnel on duty to monitor operations
- confirmation of effective and redundant communication links between ship and terminal control rooms. Most types of link include telecoms and well as ESD-1 signals, so it is possible that the former are still available or partially available. If not, alternative communication methods need to be established
- at many terminals shore personnel are routinely stationed in the ship's cargo control room to ensure effective communications. Where this is not normal practice consideration should be given to providing such personnel, at least during the most critical periods like starting cargo, ramping up to full transfer rate, topping off etc.

5 Effect of Non-Core Ship/Shore Services

Certain port states have made local regulations requiring additional services to be supplied to ships from shore when the ship is in normal service:

- On-shore power supply (so-called '*Cold-Ironing*')
- ballast and cooling water.

It is outside the scope of this paper to discuss the reasons for these proposals. However, the issue of whether these additional requirements might impact ESD philosophy in the liquefied gas industry certainly needs to be addressed. At the time of writing, there is no consensus on design concepts for these proposals and, without these details, it is difficult to be definitive about the impact on ESD systems. However, given the basic philosophy, it is sensible that the ESD-1 signal should initiate a controlled shut down of these additional services. This is to ensure that the vessel remains in a safe operational condition at all times.

As has already been stated, the industry has developed emergency release systems principally to mitigate against escalation in the event of break-out from the berth. A basic design requirement of any proposed electrical power supply from shore must, therefore, be that the ship's electrical supply is not interrupted in the event of ESD-2 and that subsequent disconnection of the electrical connection must only be achieved without creating a potential incendive spark in a hazardous area.

With respect to ESD initiators, the most hazardous material being transferred is the cargo. Therefore, it is unlikely that these additional services will generate the need for more initiators than currently recommended by the IGC Code and established practice on shore.

6 Emerging Gas Trades

The drive to commercialise marginal or stranded gas fields or to develop small scale markets has recently led to the construction of LNG carriers with onboard regasification capability, schemes involving floating LNG liquefaction and proposals for LNG shuttle tankers either to top up regas vessels or to distribute product from floating liquefaction plants. To date, there is little practical experience of these new technologies.

Notwithstanding that these are evolving technologies, the impact on the design of ESD systems needs to be carefully considered at the outset to ensure that the principles of safe shutdown and emergency release, as outlined in this document, are upheld. So far as practicable, all vessels should conform to the basic philosophy for ship/shore ESD set out in this document during periods when they are connected ship-to-ship as well as to loading or discharging terminals. Systems should be developed that will allow depressurizing and quick release of ship-to-ship cargo transfer systems in an emergency without venting gas to the atmosphere.

7 Key Recommendations

To conclude, the key recommendations of these documents are as follows:

1. For all bulk transfer operations involving liquefied gas carriers, including ship to ship transfer, linked ESD systems should be provided and used.
2. All ESD system designs must incorporate the manual and automatic initiators listed in the IGC Code. In case it is intended to include additional initiators, a rigorous examination should be conducted to ensure that such extension of the ESD system results in a real safety benefit.
3. Regular testing is imperative and contingency plans should be in place in the event of non-availability of the ESD link system.
4. System modifications to be subject to strict procedures, including documentation.
5. A functional flowchart of the ESD and related systems should be provided in the CCR.
6. Terminal operators using electric ship/shore links, in particular those using the Pyle-National connection should adopt a standardised pin configuration as outlined in EN1532.
7. For LNG carriers, if it is proposed that the design of the ESD system includes shut down of the gas burning system or gas combustion unit on ESD-1, the consequent problems of pressure rise in the cargo system should be considered. Conversely, if these systems are not to be tripped on ESD-1, then adequate safeguards must be included to ensure that the overall safety of the cargo system is not compromised (see also Part 2, Section 5).
8. All relevant shore initiation signals should be processed by the shore ESD system and passed to the ship as a single ESD-1 trip signal, not as individual signals.
9. All ship/shore links should pass ESD-1 signals in both the shore → ship and ship → shore directions.
10. All terminals should arrange for surge calculations to be performed on their specific pipeline arrangement to establish the maximum safe transfer rate achievable. The results should be retained in their permanent ship/shore reference documentation.

11. Users of electric ship/shore links that incorporate telephone connections should review the system in place to protect against an incendive spark when the cable is connected or disconnected or if the cable is accidentally severed.

8 References & Further Reading

1. IMO, 'International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk' (IGC Code), 1993 as amended.
2. IMO, 'International Convention for the Safety of Life at Sea', 1974 – SOLAS, as amended.
3. EN 1532 'Installation and equipment for liquefied natural gas – Ship to shore interface and port operations'
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5. SIGTTO, 'Guidelines for Hazard Analysis as an Aid to Management of Safe Operations', 1992
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8. SIGTTO, 'Recommendations and Guidelines for Linked Ship/Shore Emergency Shut-Down of Liquefied Gas Cargo Transfer', 1987
9. SIGTTO, 'Accident Prevention – The Use of Hoses & Hard Arms'
10. SIGTTO, 'Ship Shore Interface – Safe Working Practice'
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PART 2 – ESD FUNCTIONS AND ASSOCIATED SAFETY SYSTEMS

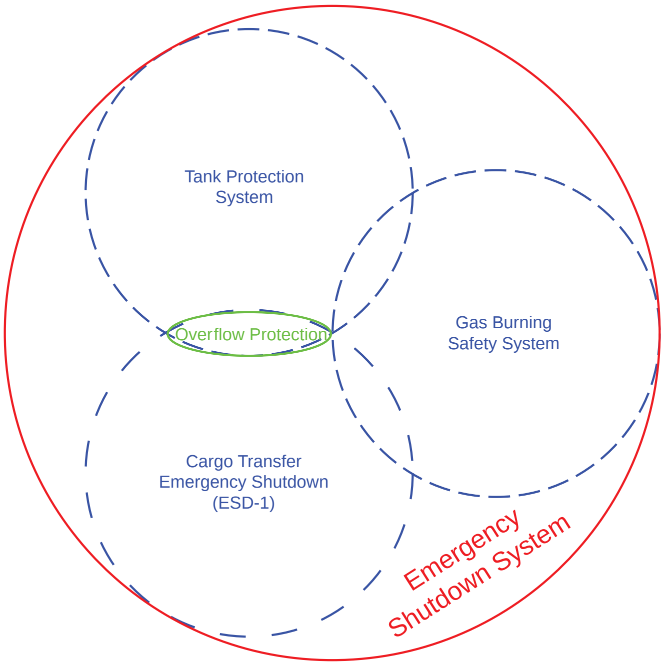
1 Introduction

Building on the general principles set out in Part 1, the purpose of this part of the document is to provide information on actual systems in service. As the worked example in this section is intended to be as generic as possible, it contains references to a variety of elements that may be encountered in gas carriers. Because of this, some of the diagrams may show combinations of cargo machinery that would be unlikely in a single ship. For example, the first logic diagram shows both a *gas fuel compressor* (found in LNG carriers with dual-fuel steam or diesel-electric propulsion) and *reliquefaction plant* (found in LPG carriers and most LNG carriers without dual-fuel propulsion).

While this Part 2 also discusses shore facilities, this is only in the context of their interaction with the ship. The information on terminal equipment and systems is, therefore, more general. The design of shore systems is outside the scope of the IGC Code and of this document.

Although, in LPG ships, it is not usual to distinguish between ESD functions concerned with loading or unloading from those associated with other operations, LNG carrier designs commonly do so and this diagram is intended to show how the functions relate to one another.

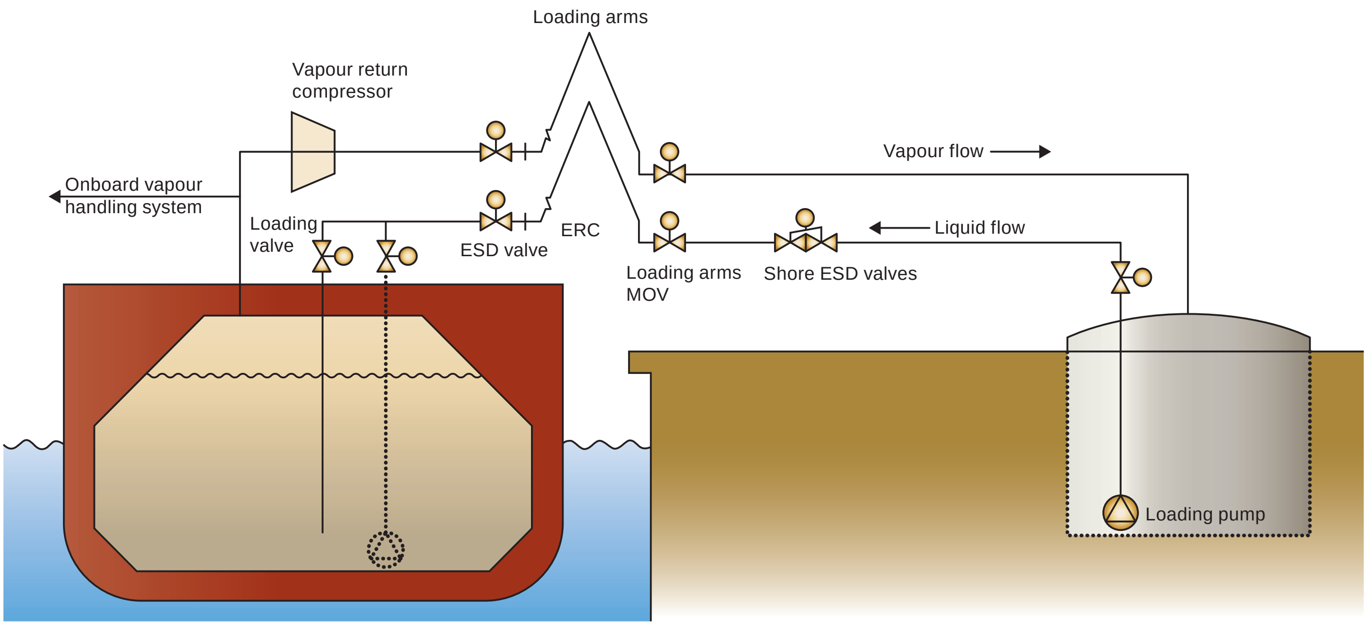
a. Based on the IGC Code core requirements centred on closure of ESD valves, the *ESD-1 system* handles cargo loading or unloading transfer operations and incorporates an ESD link to coordinate ship and shore actions.
b. Other IGC Code requirements that are centred on protection of individual tanks from damage caused by overfilling, high pressure, vacuum, etc, are handled by the *Tank protection system*
c. *Gas burning safety system* – shuts down the gas fuel supply to the engine room of LNG carriers under certain emergency conditions.



Note that there is a degree of overlap between the functions so, for example, although the *gas burning safety system* is primarily seen as an 'engine room system', it will also shutdown to protect cargo tanks against low vacuum. Although *Overflow protection* has an important role during loading, the risk is present whenever liquid is being transferred on board so it resides in both the *ESD-1* and *tank protection* areas of the diagram.

2 Cargo Transfer Emergency Shutdown System (ESD-1)

As an example, the following *Simplified Diagram of Loading Flow* shows cargo flow at an export terminal as described in this section. Liquefied gas is pumped from shore tanks to the shore ESD valves at the edge of the loading platform – this distance can be considerable. The flow then divides, typically passing to the ship's manifold via two or three liquid loading arms, and then to the ship's tanks. This arrangement is similar for all gas carriers.



Simplified Diagram of Loading Flow

However, on the vapour side, the displaced vapour and boil-off may be managed in different ways depending on the product, the type of vessel and the trade. Common examples of this may include one or more of the following options:

- Vapour return to shore, perhaps with the aid of a vapour return compressor as illustrated
- increasing tank pressure, as in the case of pressurized tanks for example
- onboard reliquefaction
- combustion onboard.

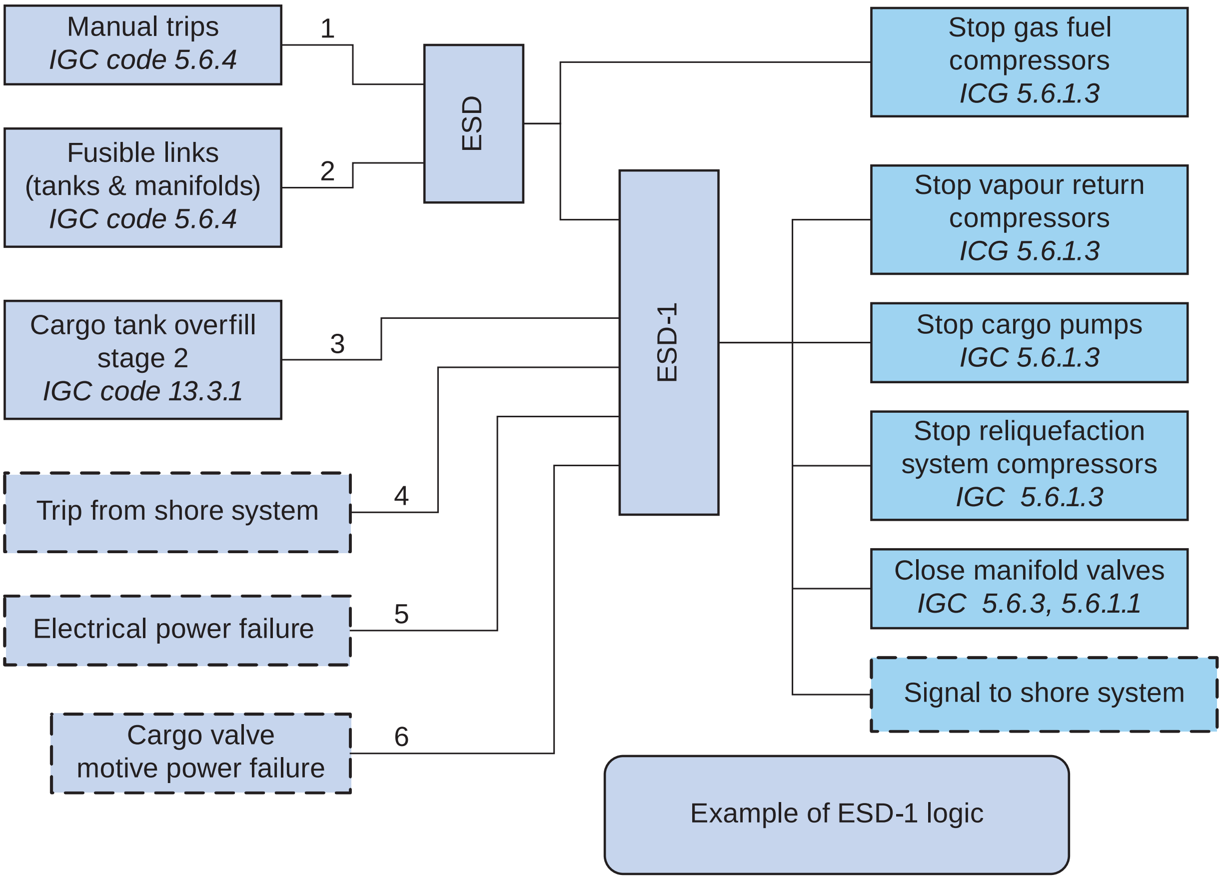
2.1 General

The ESD system minimises potential risks during the transfer of liquefied gases between ship and shore loading and unloading installations. It provides a quick and safe means of stopping the transfer of cargo and isolating ship and shore cargo systems in a controlled manner, either manually or automatically, in the event of fault conditions that affect the ability of the operator to **control safely the transfer of cargo**. Most export terminals, and an increasing number of import terminals, now have a second level of protection providing for the rapid disconnection of the loading arms from the ship.

These two levels of cover are known as *'ESD-1'* and *'ESD-2'*.

As the receiving tanks are often several kilometres from the transfer pumps, the kinetic energy in the moving liquid can be considerable and the potential hazards of surge pressure must be considered. For this reason, coordination of *ESD-1* actions requires the interconnection of ship and shore ESD systems by means of a suitable communication link.

The following diagram shows the basic components of a ship's ESD-1 logic. The numbers 1-6 relate to the initiation signals described in 2.3. 'Dashed' boxes represent functions that are not specifically defined by the 1993 IGC Code. Clause numbers in all logic diagrams in this Part 2 relate to the 1993 version of the Code and will be different in later editions.



The extra route, labelled 'ESD' in this example, is to allow LNG carriers to maintain a path for the safe disposal of vapour by avoiding unnecessary disruption to gas burning or the GCU. It may also be appropriate, in the case of LNG carrier reliquefaction plant, to treat this facility in a similar manner to the gas fuel system or GCU system. The gate is unnecessary in LPG carriers, signals 1 and 2 being input directly to the ESD-1 logic gate.

2.2 ESD Actions

2.2.1 ESD-1 (loading)

Initiation of *ESD-1* should cause visual and audible alarms together with the following actions:

Ship Action		Shore Action
Transmit ESD trip signal via ship/shore link Receive ESD trip signal from shore	→ or ←	Receive ESD trip signal from ship Transmit ESD trip signal via ship/shore link
Trip ship's **vapour return** compressors		Trip loading pumps and open spill-back valves
Close manifold valves in 25 ~ 30 seconds		Close shore ESD valves in 10 ~ 15 seconds

The shore actions above are typical for export terminals and may vary to suit the design of the plant. In some ships different machinery may be involved in this trip, such as reliquefaction plant.

2.2.2 ESD-1 (unloading)

Initiation of *ESD-1* should cause visual and audible alarms together with the following actions:

Ship Action		Shore Action
Transmit ESD trip signal via ship/shore link Receive ESD trip signal from shore	→ or ←	Receive ESD trip signal from ship Transmit ESD trip signal via ship/shore link
Trip ship's cargo pumps		
Close manifold valves in 25 ~ 30 seconds		Close shore ESD valves in 30 ~ 60 seconds

The information relating to closure of shore ESD valves given here is for general information only and the actual arrangement will reflect the specific requirements of each terminal. Import terminals sometimes incorporate additional actions into their ESD-1 logic, eg trip return gas blower.

2.2.3 ESD-2 (loading or unloading)

Initiation of *ESD-2* should cause visual and audible alarms together with the following actions:

Ship Action	Shore Action
None	Immediately initiates ESD-1[3] Closes loading arm *ERS* valves within 5 seconds Uncouples loading arm within 2 seconds of ERS valve closure

No action is necessary on the ship but it is recommended that ESD-2 is signalled by a loud audible warning on the jetty to warn personnel to stand clear of the ship's manifold area and the jetty working platform.

ESD-2 requires the provision of an emergency release system ('*ERS*') to disconnect the arms from the ship, each arm incorporating a powered emergency release coupler ('*ERC*') to achieve disconnection with minimum spillage *(dry-break* concept). Many terminals will incorporate a surge relief system. In the case of loading terminals, this may comprise a fast opening fail-safe dump valve that diverts liquid flow to a surge drum while the ERS and ESD-1 valves are closing, minimising surge.

At a few terminals systems may also be in place to disconnect the gangway automatically.

Although the ESD-2 logic is arranged as described above in the majority of LNG terminals, loading arms at some terminals are designed with an alternative logic, where an ESD-1 event triggers closure of the isolating valves within the ERC, potentially saving time if the situation then progresses to ESD-2 level. The disadvantage of this arrangement is that liquid is trapped within the ERC and in the ship's manifold for what might be a protracted period. Although many LNG carriers are now provided with liquid relief valves in the section of manifold outboard of the ESD valve, it is only in recent years that the need for such valves has been recognised and so a significant number of gas carriers will not be fitted with them.

2.2.4 Comments on ESD-1 actions

The loading arm swivels are particularly susceptible to damage caused by overpressure and it is therefore important that closure times of ship and shore ESD valves are selected with due regard to flow direction so that surge pressure is controlled upstream of the loading arm. Shore ESD valves should therefore close before the ship's manifold valves at export terminals, but after the ship's valves at import terminals.

The IGC Code states that the ship's manifold valves should be closed within 30 seconds of initiation. As it would be impractical to re-adjust closure times each voyage to suit the particular terminal, the ship's manifold ESD valves are normally standardised so that they close in 25 ~ 30 seconds.

[3] The purpose of this signal is to guarantee transfer pumps are tripped before arm release. Some terminals have alternative arrangements to ensure safe release.

Cargo valve remote control systems on many gas carriers use hydraulic actuators and for ESD valves these should be provided with pressure and temperature compensation to ensure consistent closing time.

As many types of valve actuators require hydraulic or pneumatic pressure to both close and open, the IGC Code requires the designated ESD valves to fail-closed on loss of motive power. ESD valves with hydraulic actuators are often provided with local accumulators for this purpose; while in pneumatic systems, compliance is sometimes achieved by providing actuators with individual air reservoirs. Other alternatives include spring-to-close devices. The actual arrangement will depend on the specific type of actuator but, without such provision, the valves could stay open even though they received a 'close' signal from the ESD system. The valves must be capable of local manual operation to ensure they can be closed in the event of malfunction of the actuator itself and should be provided with clear indication of valve position.

The loading of liquid nitrogen on gas carriers is now rare but, if the manifold is provided with an LN_2 connection, then it is recommended that this also be closed under *ESD-1* action, facilitating automatic disconnection under ESD-2 action at terminals so equipped.

Note that it may be only the vapour return gas compressors that are tripped as part of ESD-1 action.

Manual trips for gas fuel compressors in LNG carriers built to earlier versions of the IGC Code were usually separate from that required for the ESD system, as discussed in Section 5 of this Part 2. This was chiefly to ensure that ESD-1 events, such as a trip from shore or cargo tank high level, did not also disrupt the safe disposal of excess pressure through the gas burning system. Although this meant that the gas fuel compressors were not tripped by the deck manual trips, they could still be tripped from the cargo control room or locally. However, the introduction of operations designed to supplement natural boil-off by forced vaporization of cargo means that LNG is now often present in deck pipelines at sea. It is therefore recommended that the ESD system manual trips and fusible links also trip gas fuel compressors as illustrated in the ESD-1 Logic Diagram in paragraph 2.1. A suitable test function should be provided to facilitate ESD-1 system testing without disrupting gas burning.

Where reliquefaction systems are installed the action on an ESD-1 trip will generally be to shut down the plant, together with any associated condensate return pumps. However, special consideration should be given in the case of an LNG carrier where boil-off gas compressors are also required to service the GCU.

In general, inert gas generators in LNG carriers are never connected to the cargo system when an LNG carrier is in the cold condition and connection to ESD-1 trip logic serves no useful purpose. Overpressure cargo tank protection by tripping the inert gas generator is therefore a function of the *Tank Protection System* described in Section 4 of this Part 2. This may be different to some LPG carriers where, if cargo pumps fail, the inert gas system can be used for the emergency discharge of cargo by pressurizing the tank. In this case it should be tripped by ESD-1.

2.3 ESD Initiation

2.3.1 Initiation signals

An *ESD-1* trip may be initiated by the following:

Ship Initiation	Shore Initiation
1 Operation of manual trip	A Operation of manual trip
2 Fire at tank domes or manifold area	B Fire in terminal area
3 Overfilling of any cargo tank (HHL)	C Overfilling of receiving tank (import terminal)
4 Shutdown signal from shore via link	D Shutdown signal from ship via link
5 Loss of electrical power	E Loss of electrical power
6 ESD logic failure	F ESD logic failure
7 Loss of system pressure in the cargo valve remote control system	G Loss of actuating power to the common loading arm manoeuvring system or to the ERS of individual loading arms
	H High level of liquid in surge drum (where provided)
	I Excessive movement of ship from berth (stage 1 – pre-alarm)
	J Activation of ESD-2

Some of these initiators will not apply at all terminals.

An *ESD-2* trip should be initiated in the event of the following conditions:

Ship Initiation	Shore Initiation
Not activated from ship	K Operation of manual trip
	L Excessive movement of ship from berth (stage 2 – disconnect)

2.3.2 Comments on ESD-1 initiation signals

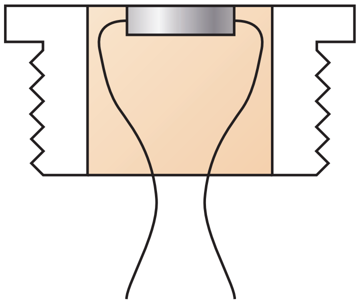
Ship

Signal 1 (operation of manual trip) will be derived from manual switches or push buttons. The IGC Code requires a minimum of two points, one of which must be in the cargo control room (or equivalent). Manual trips should be located so they can be reached reasonably quickly by anyone spotting a serious hazard. Consideration should be given to installing additional points where free access is restricted, by fore and aft pipelines for example. The optimum position is alongside primary escape routes. The manual ESD should not form part of any other shutdown system.

Signal 2 (fire in the cargo area) will be derived from ***fusible links*** installed in the cargo area. The IGC Code requires sensors at the tank domes and the loading stations that will operate in the range 98 ~ 104°C. Originally these comprised a pipefitting blocked with a soft metal plug that would melt on contact with fire, releasing air pressure from the air security pipework. They are often still called *fusible plugs* for this reason. This type of system is illustrated in Part 3, Section 1.

The first electrical systems employed bi-metallic switches but these tended to be delicate and unreliable. Fault detection could be difficult and later systems often incorporated additional wiring to aid fault finding.

Thermal fuses are commonly used for this application. These devices are readily available in the appropriate temperature range and have the advantages of being both cheap and reliable. The usual arrangement is to bury the thermal fuse in a silicon mould using a gland nut as a former, as illustrated here. Two such modules, connected in parallel, can be installed in a 4-way junction box to create a standard fusible link unit. Fusible link units can then be series-connected and monitored by an IS relay mounted in the safe area.



The IGC Code requires that where separate gas and liquid domes are fitted, both should be protected.

Signal 3 (overfilling of any cargo tank) in the system described here is derived from the higher of two 'spot' level sensors in each of the ship's cargo tanks. In this example this *HHL* sensor will be independent of the main level measuring system and arranged so that the operation of any one sensor will initiate *ESD*-1. This is covered in greater detail under 'Cargo tank overflow protection' on page 18, where subjects such as *two-stage overflow protection* and *signal blocking* are also discussed.

Signal 4 (shutdown signal from shore) will be transmitted by means of a ship/shore link. These are discussed in Part 3.

Signal 5 (electric power failure) In the event of electrical supply failure, the ship's cargo pumps and electric-driven gas compressors will shut down without any intervention from the ESD system. Depending on the actual arrangement, the ship's manifold ESD valves could remain open until hydraulic pressure collapses. However, without **signal 5** shore loading pumps and compressors would continue to run under ship's blackout conditions.

Signal 6 (loss of actuating power to the cargo valve control system) The source of this signal will depend on the type of valve actuators employed. For hydraulic or pneumatic systems the source should be a low-low pressure switch installed in the common supply line **downstream of any isolating valve**. Pre-alarms will also be fitted and signals should have suitable time delays.

Note: the primary purpose of this signal is to stop transfer in the event the operator loses the ability to adjust valves in the system, particularly tank loading valves or pump discharge valves. Therefore, the pressure being monitored must **not** be a maintained supply such as a manifold ESD valve accumulator.

Signal 7 (ESD logic failure). Historically, this signal was added when ESD systems started to rely on early electronic logic devices, such as programmable logic controllers, and was intended to cover an internal system failure (such as fuse blowing in the system). The necessity for such an input will depend on the type of logic and the level of redundancy but, with a robust DCS/IAS, a separate signal may be unnecessary.

It is recommended that the ESD system be designed to indicate positively the source of a trip.

Shore

For completeness, this short paragraph will cover some of the shore elements shown in the table at the beginning of this section 2.3. Many factors will determine the exact arrangement of shore ESD systems, not the least of which is whether it is an export or an import terminal. A detailed discussion of the inputs to **shore** ESD systems is outside the scope of this document, which is intended only to cover the parts affecting the gas carrier, ie the cargo loading or receiving system.

Signal I (excessive movement of ship away from berth) is usually derived from a first stage signal of the loading arm apex angle and/or slew angle transmitter.

Signal J (activation of ESD-2) is derived from interlocked monitoring circuits in the ERS and forces ESD-1 activation to ensure that in the event of premature release, cargo flow will have ceased.

The other signals listed are similar to their counterparts on the ship.

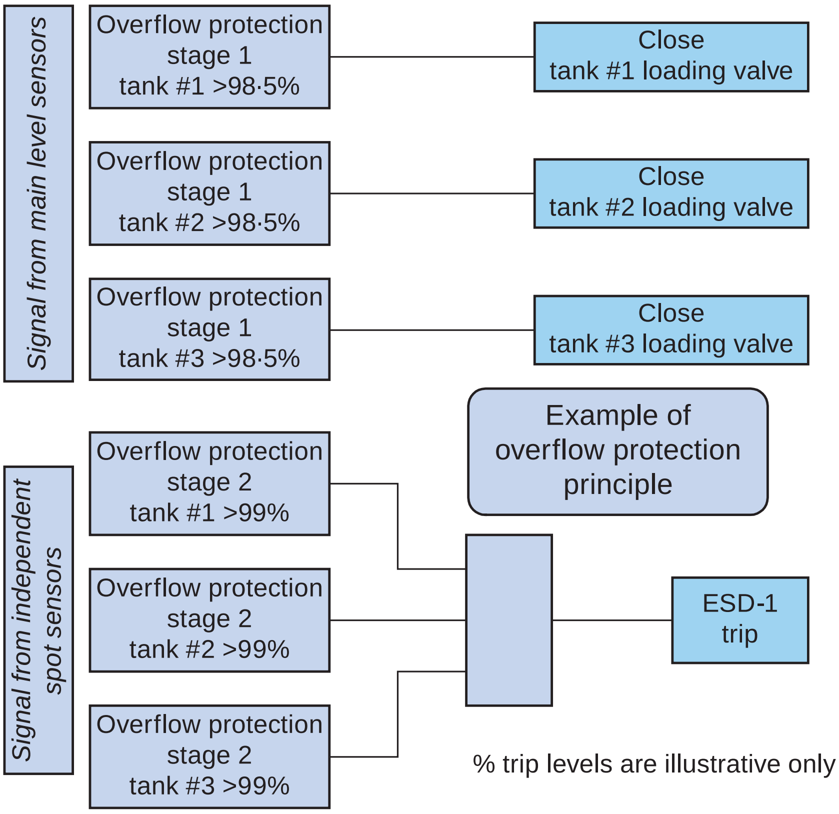
Additional ESD-1 Trips

The simpler the system, the easier it will be to understand, test and maintain and the ESD-1 initiators described above will normally be adequate. Advances in technology have opened up the opportunity to engineer a whole range of automatic initiators of linked ESD systems but great caution should be used when considering further initiators beyond those required by the IGC Code and mentioned above on ships and those currently established on shore. Any such proposals should be subject to rigorous assessment to ensure that there is a real benefit.

3 Cargo Tank Overflow Protection

Although IGC13.3.2 deals with overflow control it is clear from the wording that the counter measures are aimed at preventing an overflow *during loading*. However, the majority of overflows have actually occurred during discharge due, for example, to a valve being left open to a full tank.

As stated earlier, in addition to an independent high level alarm, the IGC Code requires another level sensing device to close a valve to prevent tank overflow. The Code allows this to be either the "*emergency shutdown valve*" or "*another valve*". Although not stated, this infers that the valve should be on the tank filling connection. As the manifold valves are the designated ESD valves in LNG and many LPG carriers, the level of protection from solely closing the manifold valves would clearly be seen as inadequate. Perhaps the simplest way to enhance the basic requirements of the IGC is to also arrange for the tripping of cargo pumps as part of overflow protection. In many ships this provides an adequate level of protection. However, many vessels are generally equipped with level measuring and protection systems that allow a more sophisticated solution to be adopted. The 'high level alarm' requirement is now typically met by duplicated sensors giving two independent alarm signals, while CTS systems generally provide up to four more 'alarm' outputs.



Although the arrangement shown here would not be practical in all types of gas carrier, it is often applied to LNG carriers and satisfies the IGC requirement for independent signals. This design has been used for many years and provides a proper level of protection with appropriate redundancy. For clarity, only three tanks are shown.

As the diagram shows, there are two stages of shutdown: firstly closing the tank loading valve in the affected tank and then, should the level continue to rise, initiating an ESD-1 trip to halt the entire transfer process. In addition, audible and visible alarms are given at appropriate points.

Main sensor refers to the primary CTS[4] level gauge. Most systems provide up to four volt-free contacts for alarm purposes.

Spot sensors, which trigger at a specific level, operate independently of the CTS. There is one output per sensor and modern systems have two sensors per tank.

[4] Read 'main level gauge' in trades where no CTS is provided

The following sequence will occur as the tank level rises:

1. Pre-alarm – sourced from the lower of two independent 'spot' sensors. It is recommended that this be set so that, when loading at maximum rate, it operates about 15 minutes before reaching normal filling level. In this example, this will be around 97% volume.
2. Close tank loading valve – sourced from main sensor and set at about normal filling level. Typically this will be 98·5% for a membrane system or 99·5% for a spherical tank, the actual figure being calculated to take into account trim and list and to avoid premature actuation.
3. ESD-1 – sourced from upper spot sensor (HHL) to prevent the tank becoming liquid full. Typically settings are 99·0% for membrane or 99·7% for a spherical tank. Note that this will leave the tank overfilled and action will have to be taken to reduce the level to normal before sailing.

If allowed to continue, the above sequence would close each tank loading valve in turn before the level reached the HHL shutdown sensor. When the last valve closed, the effect would be to close against loading flow without ESD-1 initiation. To ensure that this is not possible, the control logic must be designed to initiate an ESD-1 trip if **all** loading valves are closed or, in the case of the last valve, are closing. However, even with this degree of sophistication, good operating practice would ensure that this critical stage of loading was only carried out under close direct supervision.

An advantage of using main CTS sensor for closing the loading valve is that the trigger point can be finely adjusted to suit the actual valve closing characteristics. By contrast, most spot sensors have very limited adjustment capability.

Reliability, rather than extreme accuracy, is more important to the ESD-1 signal, which the independent sensor provides.

As the main gauge is monitored throughout loading, the operator will have been alerted to any problems with this system that might exist and this gives reasonable confidence that the signal to close the filling valve will actually work. Similarly, sourcing the pre-alarm from the independent system increases the likelihood that any faults in that system will be revealed before ESD-1 level is reached, at the same time providing a cross-check of the accuracy of the two systems.

All level signals should have suitable time delays to avoid premature shutdowns caused by surface motions of the cargo.

Signal blocking

To avoid unnecessary alarms caused by the cargo motions, it is normal practice to disable ('block') the level sensors at sea. The obvious danger with this is that someone will forget to unblock the signals before a transfer operation begins. Although the risk is mitigated to some extent by having prominent warning indicators, it is recommended to also have effective interlocking. For example, it should not be possible to simultaneously block both filling valve close signals and the ESD-1 trip level signals in the same tank, and it should not be possible to open the manifold valves when any ESD-1 trip level signal is blocked.

Blocking of individual sensors is also necessary in two other circumstances:

- If a tank becomes overfilled to the point that the upper independent sensor operates, this sensor will have to be blocked to enable cargo pump starting so as to reduce the level
- the most positive way of testing the whole system is to deliberately overfill each tank by a controlled sequence of internal transfers for which selective blocking is necessary. To satisfy periodic survey requirements such a test is normally carried out at the end of loading the first cargo on delivery or after refit.

In service it is also common practice to temporarily block the filling valve close signal in the last tank to be filled while 'topping off' and during line draining.

Custody Transfer and Independent Level Alarm systems may be provided with physical 'block switches' and sometimes software blocking as well, and this may not be immediately obvious to the operator.

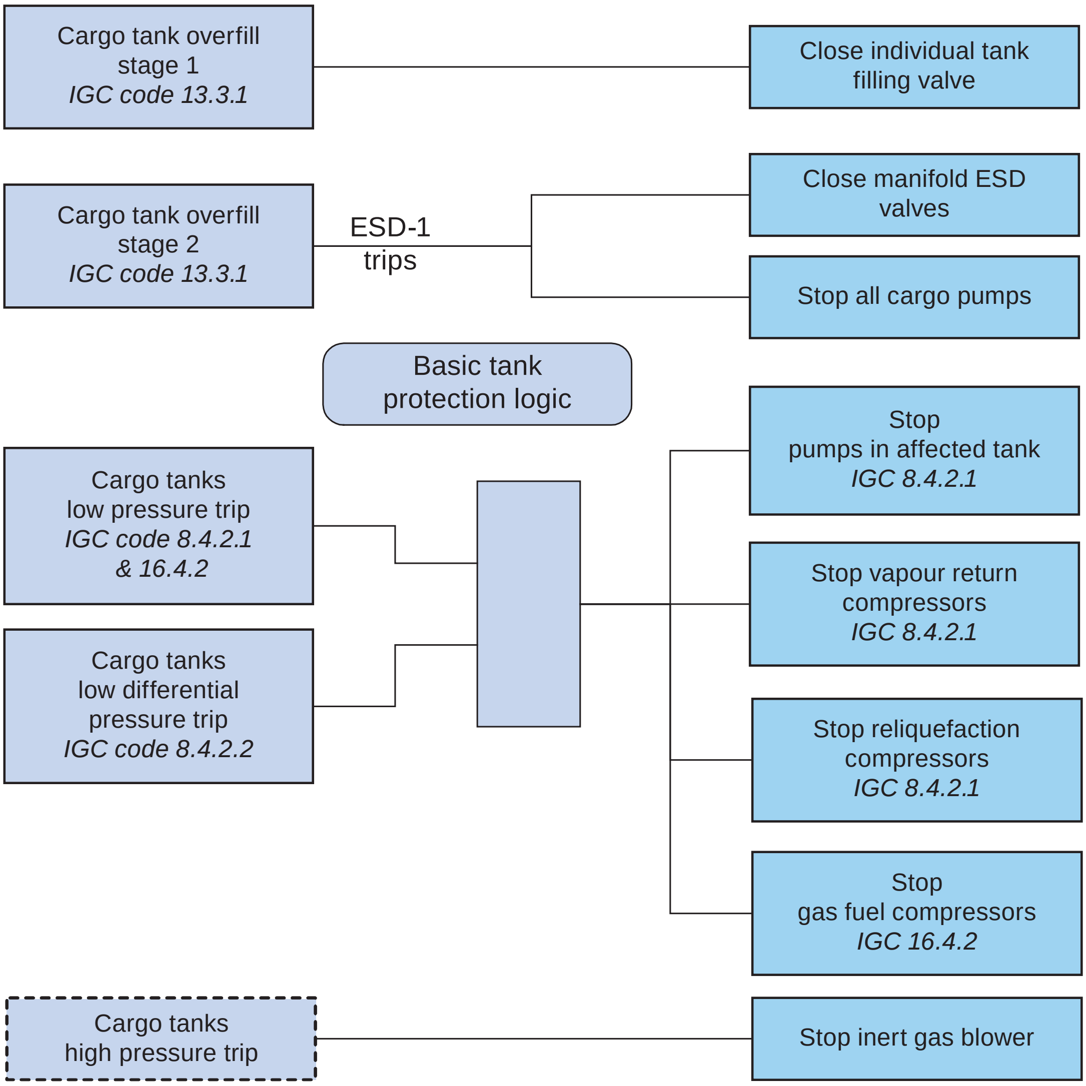
Testing

In the system described above, the lower independent spot sensor alarm and the normal filling level trip can be tested during routine loading. The operator can also gain confidence by observing the level at which these signals **clear** during discharge.

The upper (ESD-1 level) independent sensor should be tested on first cargo and following significant maintenance. This is described in Appendix C.

4 Tank Protection

This system shuts down appropriate machinery to protect the cargo containment system against damage caused by over pressure, under pressure or overfilling. Overfilling was covered in the previous section. The system acts independently of ESD-1, although some functions may be shared to a greater or lesser degree depending on the type of gas carrier. This is particularly true in LPG carriers designed to handle two or more grades, which are often arranged so that all cargo machinery is tripped by the ESD irrespective of whether caused by an ESD-1 trip or tank protection trip.



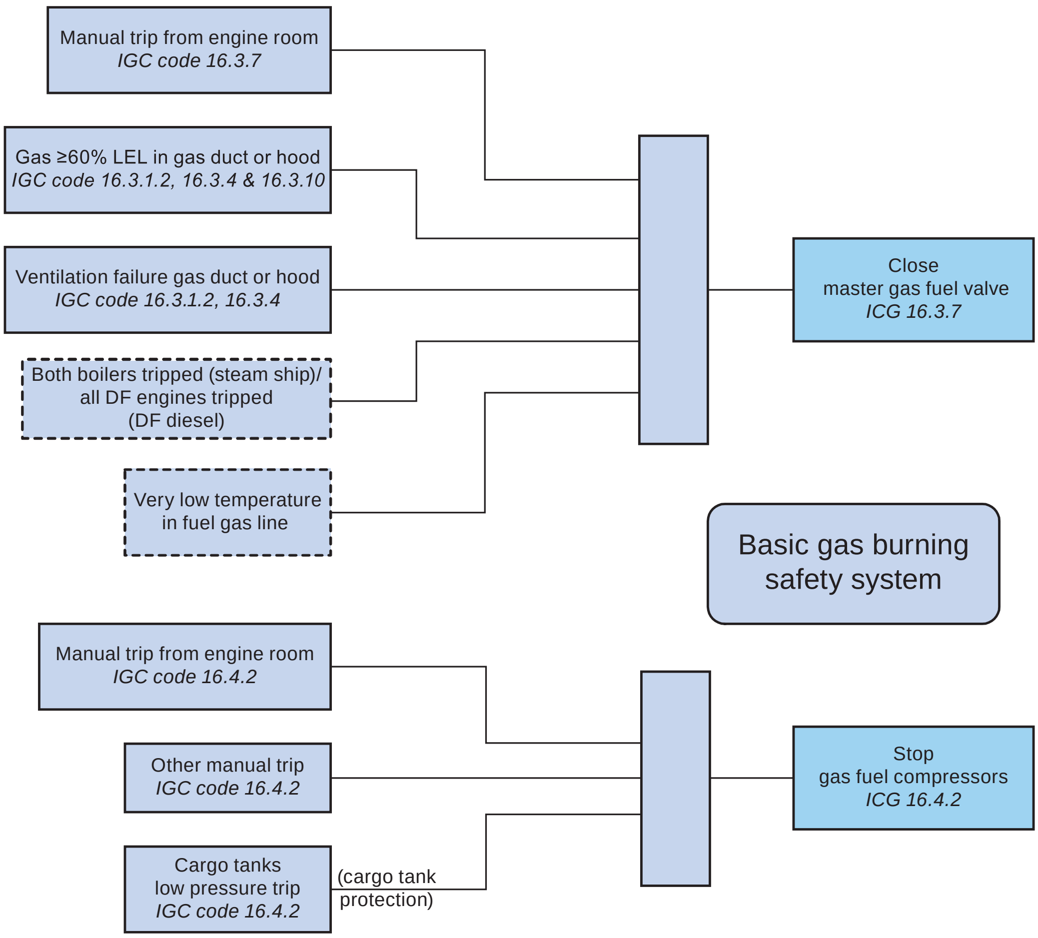
The system depicted above, which has been simplified for clarity, represents a typical containment system that requires protection against vacuum in the cargo tanks and high differential pressure across the barriers or insulation spaces. Separate pressure switches (or equivalent) are required to provide alarm and trip signals to stop all machinery drawing suction on the tank. Although the diagram shows only cargo pumps, any other type of pump connected to the tank will also be tripped (eg spray pumps, LNG fuel pumps). Similarly, on the vapour side, the types of gas compressor actually fitted will depend on the type of ship. An LNG carrier with reliquefaction typically will have vapour return compressors and boil-off gas compressors, while refrigerated LPG ships may have only the compressors associated with the reliquefaction plant.

The diagram shows a high pressure trip. The necessity for such a trip will depend on the operating pressure and design of any inert gas plant installed. This trip will be set slightly below MARVS.

5 Gas Burning Safety System

A detailed treatise on these systems is outside the scope of this document and this section will just provide an overview, concentrating on the interface with the cargo system.

As the name implies, the purpose of this system is to protect the machinery spaces by closing off the gas supply under certain emergency conditions. Isolation of these spaces from the gas supply is achieved by tripping the master gas fuel valve, which is located in the cargo area. A basic requirement of the IGC Code is that there must be a manual trip point in the engine-room and automatic closure on ventilation failure or in the event of high gas concentration.



IGC 16.3.7 requires that the master gas fuel valve can be closed from within the machinery space and the more usual interpretation is that there should be a physical *gas burning emergency trip* 'button' on the engine control console. It is recommended that this should be a self-latching device so that resetting requires a conscious and deliberate act. A hinged cover should be provided to reduce the likelihood of accidental operation.

IGC 16.4.2 requires that Gas Fuel Compressors "*should be capable of being remotely stopped from a position which is always and easily accessible, and also from the engine-room*". The latter is most easily fulfilled by using the same *gas burning emergency trip* device already described. As a core requirement of the fire control centre is that it is "*always and easily accessible*", this is an ideal location for the alternative gas fuel compressor trip point.

It is recommended that on detection of the master gas fuel valve leaving the full-open position, gas fuel compressors are automatically stopped and, on actual closure, the line downstream of the valve is automatically purged of gas by using nitrogen.

Unlike all other trips shown in this diagram, the purpose of the cargo tank low pressure trip is not for the safety of the gas burning system but for the cargo containment system.

PART 3 – LINKED ESD SYSTEMS

This document outlines the systems currently in use at liquefied gas terminals for data transfer between ship and shore, commonly known as the ship/shore link (SSL).

1 Pneumatic ESD Link System

The earliest ship/shore links used in LNG projects were simple pneumatic umbilical links, an air hose coupled directly into the ship's *air security system*. Such systems are inherently slow in operation, suffer from problems caused by dirt or moisture and it is difficult, if not impossible, to achieve accurate and repeatable timing. The designer must be aware that the diameter of the pipework and dump valve can significantly influence the closing time.

These drawbacks have led to the development of electronic ESD systems with fibre-optic or various intrinsically-safe electric systems providing the ship/shore link.

However, despite its disadvantages, having a pneumatic link is better than having no ESD link at all.

Details of the pneumatic link are provided in Appendix D.

2 Electric Ship/Shore Link Systems

The first intrinsically-safe electric ship/shore link was installed at the LNG stern loading berth at Lumut, Brunei, in 1972. This unique system provided both ESD-1 and ESD-2 as well as telephone signals. It was later replaced by a fibre-optic link when the original berth was replaced by a conventional loading berth.

2.1 Pyle National Electric System

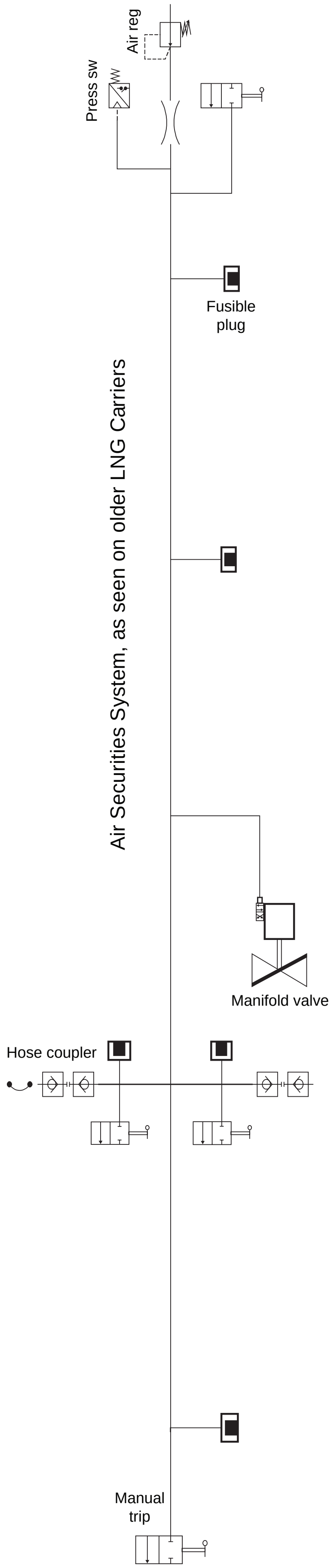
The second electric system to be used was introduced by the El Paso Corporation in 1976 for the Bethouia, Algeria to Cove Point LNG project. The cable, comprising 16 shielded pairs, was connected at each end using Pyle-National 'AF' series explosion-proof control connectors. This system was subsequently adopted by other terminals receiving LNG from Algeria.

These systems are primarily in use in the Atlantic Basin, Europe and Mediterranean ports but may also be found in addition to alternative systems in ports in West Africa, the Middle East and India. Up until 2009 about 70% of all LNG carriers and 50% of LNG terminals had systems based on the Pyle-National cable connection.

The original configuration provided for ESD-1 signals in each direction and three telephone connections, as well as continuity loops and various other signals that were peculiar to individual berths. Regrettably, there are now numerous idiosyncratic pin configurations in use at many terminals.

Details of the system, including the preferred pin configuration, are shown in Appendix E.

Although variations in pin configurations generally could be accommodated with dedicated ships in liner trades, ship/shore links based on the Pyle-National connector have now been adopted at over forty-five LNG terminals. It has also been adapted to suit systems on many more LNG carriers, many of which are engaged in cross-trading so, despite the efforts of one particular supplier to standardise, compatibility is becoming increasingly difficult with the burgeoning LNG trade. Without any overall control there is also the danger of insufficient regard to limiting energy in telephone connections, for example.



2.2 ITT-Cannon Telephone Link System

Unlike the other systems described in this section, this link does not provide ESD functionality but the description is included in the interests of completeness. The system was introduced when the export of Indonesian LNG started in 1977, and uses a MIL-STD 13 pin connector to provide telephone functions only. It was installed at the Indonesian export terminals in Bontang and Arun and LNG receiving terminals in Western Japan and Yung An, Taiwan.

As the system is not 'certified safe' the shipboard connector is installed aft of the accommodation. ESD functionality was originally by pneumatic link. All the Japanese terminals have since been equipped with fibre-optic systems.

See Appendix F for details.

2.3 Miyaki Electric System

This electric system was first installed at the start-up of the Malaysia LNG project in 1983. The original system, installed at the export terminal at Bintulu and the Japanese receiving terminals at Sodegaura, Higashi-Ohgishima and Futtsu, comprised of three cables each connected by a colour-coded Miyaki Denki 21-E-PT explosion-proof connector. One connector was used for ESD and the other two for telephones. The ESD link originally operated only in the ship to shore direction at the loading terminal, and in the opposite direction at the discharge terminals, but it was subsequently modified to provide signals in both directions at Bintulu and in some Japanese terminals. The fibre-optic system was later adopted as the primary ship/shore link for this project, the Miyaki link being retained only as a back-up system. In Japan, this design of ESD link is still in use for some LPG projects.

However, Miyaki Denki 21-E-PT connectors were also used when Korea began importing Indonesian LNG into Pyeong Taek in 1986. Only two cables are used in the Korean terminals and the pin configuration is different to that used for the Malaysia/Japan project. One connector provides an ESD-1 shutdown signal (shore → ship direction only), the other connector is used for telephones.

See Appendix G for details.

2.4 SIGTTO Electric Link System

This system was the result of a collaborative effort by SIGTTO members to produce a standardised, intrinsically-safe delay-free ESD link using standard components as described in '*Recommendations and Guidelines for Linked Ship/Shore Emergency Shut-down of Liquefied Gas Cargo Transfer*' [8]. The system is available as a package from Measurement Technology Ltd (MTL), although because standard interface components are used, other manufacturers are free to produce a compatible link. The advantages of the system are that it provides an ESD-1 signal in both directions; 'arming' the link requires resetting in a particular sequence. The whole system is designed and certificated to ensure its intrinsic-safety is not compromised and it incorporates features for testing and fault indication. The standard 'kit' includes a pendant extension unit intended as an interim measure for use where no alternative ESD ship/shore link is available.

They are generally used in LPG and chemical gas transfer operations where many LPG carriers in the international trades are so fitted.

Although the system has been installed in a few LNG carriers to maximise spot trading advantages, none of the major international LNG projects has adopted the SIGTTO link as the primary system and, to date, the use of this system within the LNG sector has been limited to the Norwegian LNG coastal network, operating small LNG carriers. LNG projects generally require telephone signals, and sometimes other data, to be sent via the ship/shore link. While the SIGTTO link has advantages over other electric link systems in terms of assured intrinsic-safety and standardisation, the system is limited to ESD functions and is not able to pass other signals, a factor which will have effectively ruled it out as a candidate for selection by new LNG projects.

However, as only two of the five pins in the 'international connector' are required for the ESD function, a pair of spare cores could be made available for other functions while still allowing compatibility with existing installations. Now that intrinsically-safe multiplexers are readily available it **may** be feasible to use this technology to pass a variety of data signals via the unused spare. The fibre-optic system uses a four-channel multiplexer for telephones and for exchange of mooring tension data, but as IS-multiplexers with up to 64 channels are already in use in the gas industry, the potential exists to expand the use of the SIGTTO link for telephony and data transfer. If there is sufficient support within the industry for enhancing the SIGTTO Link in this way, it should be developed as a collaborative effort to ensure that equipment and selection of data channels is standardised

Details of the standard SIGTTO link are provided in Appendix H.

3 Fibre-Optic Ship/Shore Link System

The first optical fibre link system was developed by Sumitomo in association with Furukawa, and came into commercial use at Japanese LNG terminals in time for the start-up of the Australian North West Shelf project in 1989. A compatible system was later developed by SeaTechnik, initially to supply markets outside Japan.

The system uses a 6-core fibre-optic cable; two used for an ESD-1 signal in each direction; two cores used with a multiplexer to provide four data channels; two cores spare. One of the data channels is normally reserved for mooring load monitoring and the other three for telephones.

Compatible fibre-optic systems are used in Japan, Korea, Malaysia, Indonesia, Australia, India, Middle East, Africa, UK and the US. Until 2009, about 90% of all LNG carriers and 65% of all LNG terminals had links based on this system. Details are provided in Appendix I.

4 Radio Ship/Shore Link System

The original ship/shore link at Withnell Bay LNG Terminal comprised two radio links, one for ESD and one for telecommunications. The system provided the same functionality as the fibre-optic system already installed on the dedicated North West Shelf ships. Both radio systems proved unreliable and, eventually, were un-maintainable. The system was abandoned and replaced by a SeaTechnik fibre-optic link system in 2003.

Radio ship/shore ESD links are generally considered unsuitable for the following reasons:

1. Radio regulatory regimes differ considerably around the world and the continuing commercial demand for bandwidth require existing allocations to change from time to time, often at short notice.
2. The unlicensed low-power UHF bandwidths in the 430MHz region have very limited bandwidth for other than ESD signals and the rapid growth of simple commercial and domestic applications leads to failures due to local interference. This is less of a problem in remote desert export terminal areas than for the import terminals which are often located in industrialised and populous areas.
3. The presently unregulated UHF bandwidths in the 2.4GHz region have much wider bandwidth capability but the demands on bandwidth for both simple and complex applications, such as WiFi radio LAN networks, are growing exponentially.
4. The duplex (bi-directional) ESD has to be fail-safe but with a response time of 500 ms or less. The consequences of a spurious trip are commercially and operationally severe particularly for LNG transfers.

5 Choice of Ship/Shore Link System

Generally, the LNG industry uses fibre-optic and/or electric link systems. At one time the split was roughly geographical, with the Pyle-National electric being the usual choice in the Atlantic basin and fibre-optic systems being the most popular in the Pacific. However, with the expansion of the industry and ships engaged in cross-trading, this rule is no longer valid as some LNG terminals in the Atlantic region have installed fibre-optic systems, while Pyle-National electric systems have been installed at a few terminals in the eastern hemisphere. The decision to fit both fibre-optic and electric systems is generally a commercial matter to enhance the flexibility of the terminal when dealing with vessels on spot trades.

While the fibre-optic system has a standard pin-configuration this is not true for electric links, particularly the Pyle-National connector. Ideally, all terminals using the Pyle-National should agree a standardised pin-configuration but, given the difficulty of arranging this with ships already in service, this is probably unrealistic. However, for **new terminals**, care should be taken to ensure that no further variations are introduced by adopting the pin-out shown in the Appendices.

The LNG industry generally uses the pneumatic link as a back up to the primary ship/shore link.

In the LPG & chemical gas industry the most popular system is the SIGTTO link, which is the *de-facto* standard for many of the larger LPG carriers. This sometimes causes problems at export terminals with dual purpose jetties capable of accommodating both LNG and LPG carriers, as these terminals often only have an LNG type of link system. It is recommended that consideration be given to providing a standard SIGTTO link at these berths for use when LPG is loaded.

PART 4 – APPENDICES

Referred to in Part 1

A 1993 IGC code requirements relating to ESD systems

Referred to in Part 2

B ESD processing

C Testing of linked ESD systems for gas carriers

Referred to in Part 3

D Pneumatic ESD links

E Pyle-National electric link connector

F ITT-Cannon telephone connector

G Miyaki Denki electric link connector

H SIGTTO electric link system

I Fibre-optic link connector

Appendix A 1993 IGC Code Requirements for an ESD System

Introduction

The IGC Code specifies that an Emergency Shutdown System (ESD) is to be fitted for the cargo system, but the requirements are rather fragmented throughout the Code. The purpose of this Appendix is to clarify the intention of the current IGC Code requirements for ESD systems, pending the review of the IGC Code now in progress. To aid understanding, the wording from the IGC Code is replicated in shaded boxes. Where appropriate, SIGTTO recommendations are in italics to differentiate from explanatory text.

The main purpose of the ESD system is to stop cargo flow in the event of an emergency and to return the system to a safe, static condition so that any remedial action can be taken.

In port, with cargo flowing between ship & shore, the emergency situations considered include, for example, fire, leakage from hoses or hard arms, cargo tank overflow aboard the vessel and an emergency on the jetty.

For cargo flows within the ship, the scenarios envisaged include, for example, emergencies involving boil-off reliquefaction, cargo liquid recirculation operations (such as re-heating or cargo co-mingling) and boil-off supply as fuel to the engine room. These situations can arise either in port or at sea.

A primary consideration when designing the ESD system must be to avoid the potential generation of surge pressures within cargo transfer pipework if a valve closes during transfer.

The basic principle is that, for cargo systems with low-pressure containment, the system should stop any cargo machinery that is running (eg cargo pumps or compressors) and, in port, close any valve connections to shore to isolate the ship and shore systems. In addition, for cargo systems with Type C pressurised containment, tank dome valves should also be closed by the ESD system in recognition of the potentially higher leakage rates should a pressure system fail.

As a minimum, the IGC Code requires that the ESD system shall be activated by the manual and automatic inputs identified within this appendix. Designers should only incorporate any additional inputs into the ESD system if it can be shown their inclusion does not reduce the integrity and reliability of the system overall.

SIGTTO recommends that all gas ships' ESD systems should incorporate a standard ship-shore link, in accordance with SIGTTO guidelines, to enable ship and shore ESD systems to be linked when transferring cargo.

Specific Requirements of the IGC Code for Equipment & Control Systems

For clarity, the IGC Code requirements will be set out, paragraph by paragraph, with explanatory notes. To assist the present review, the paragraphs are separated into bullet points and re-ordered slightly. Although each entire paragraph is included here, parts that are less relevant to the topic under discussion are shown in a lighter colour for clarity.

Valve requirements for 'low pressure' ships (eg fully refrigerated LPGCs or LNGCs)

5.6.1.1	• For cargo tanks with a MARVS not exceeding 0.7 bar gauge, all liquid and vapour connections, except safety relief valves and liquid level gauging devices, should have shutoff valves located as close to the tank as practicable. • These valves may be remotely controlled but should be capable of local manual operation and provide full closure. • One or more remotely controlled emergency shutdown valves should be provided on the ship for shutting down liquid and vapour cargo transfer between ship and shore. Such valves may be arranged to suit the ship's design and may be the same valve as required in 5.6.3 and should comply with the requirements of 5.6.4.

This section specifies that all tank dome connections on 'low pressure' ships must be fitted with at least manual closing valves, except for level gauges and relief valves which are covered in 5.6.2 and 8.2.8 respectively. It is optional to fit these manual closing valves with remote-actuation devices. However, it is mandatory to fit remotely operated valves in the liquid and vapour systems to stop cargo transfer with shore. This paragraph introduces the concept that one purpose of the ESD system is to stop cargo transfer between ship and shore.

Valve requirements for 'pressure' ships (eg pressurised or semi-refrigerated LPG or ethylene carriers)

5.6.1.2	• For cargo tanks with a MARVS exceeding 0.7 bar gauge, all liquid and vapour connections, except safety relief valves and liquid level gauging devices, should be equipped with a manually operated stop valve and a remotely controlled emergency shutdown valve. These valves should be located as close to the tank as practicable. • Where the pipe size does not exceed 50 mm in diameter, excess flow valves may be used in lieu of the emergency shutdown valves. • A single valve may be substituted for the two separate valves provided the valve complies with the requirements of 5.6.4, is capable of local manual operation and provides full closure of the line.

The requirements for pressure systems recognise the increased leakage risk and require duplicated valves at each tank connection; one operated manually the other with remote actuation. It is possible to combine the two valves as long as the single valve can be closed both locally and remotely. Level gauges and relief valves are again exempted. In recognition of the restricted pipe sizes that may be used in pressure systems, 'excess flow valves' are permitted in lieu of remote-operated ESD valves for line diameters up to 50 mm (see also 5.6.5).

Valve requirements for excess flow valves

5.6.5	• Excess flow valves should close automatically at the rated closing flow of vapour or liquid as specified by the manufacturer. The piping including fittings, valves and appurtenances protected by an excess flow valve should have a greater capacity than the rated closing flow of the excess flow valve. Excess flow valves may be designed with a bypass not exceeding an area of 1·0 mm diameter circular opening to allow equalization of pressure, after an operational shutdown

ESD valve requirements for gauging or measuring devices

5.6.2	• Cargo tank connections for gauging or measuring devices need not be equipped with excess flow or emergency shutdown devices provided that the devices are so constructed that the outward flow of tank contents cannot exceed that passed by a 1·5 mm diameter circular hole.

These two paragraphs, 5.6.2 and 5.6.5, are self-explanatory and limit the potential release from failures involving these systems.

ESD valve requirements at transfer connection in use

5.6.3	One remotely operated emergency shutdown valve should be provided at each cargo hose connection in use. Connections not used in transfer operations may be blinded with blank flanges in lieu of valves.

This requirement applies to both 'low pressure' and 'pressure' systems, and requires ESD valves at the shore connection in both cases. For 'low pressure' ships, these manifold valves may be the only ESD valves fitted while for 'pressure' ships, the manifold ESD valves are in addition to those fitted at the cargo tank in accordance with 5.6.1.2.

The ship's manifold pipework outboard of the ESD valve must be designed to withstand the maximum calculated surge pressure at the loading terminal(s) – see IGC 13.3.1. The same pressure rating should be applied to any blank flanges used for blinding manifold connections. Lightweight (weather) blanks should not be used for this purpose.

Manifold connections should be designed in accordance with the relevant SIGTTO/OCIMF Guidelines and should be of adequate strength to withstand the forces imposed by the loading arms. Torsional forces imparted by the separation of emergency release couplers also need to be considered.

SIGTTO also recommends that the section of line between the manifold valve and connection flange is protected by a liquid relief valve in accordance with IGC 5.2.1.6. The relief capacity must be sufficient to handle not just the contents of the ship's connection but also the parts of any loading arms and emergency release couplers still connected to the ship after an ESD-2 event.

Control systems for ESD valves

5.6.4	• The control system for all required emergency shutdown valves should be so arranged that all such valves may be operated by single controls situated in at least two remote locations on the ship. One of these locations should be the control position required by 13.1.3 or cargo control room. • The control system should also be provided with fusible elements designed to melt at temperatures between 98°C and 104°C, which will cause the emergency shutdown valves to close in the event of fire. Locations for such fusible elements should include the tank domes and loading stations. • Emergency shutdown valves should be of the fail-closed (closed on loss of power) type and be capable of local manual closing operation. • Emergency shutdown valves in liquid piping should fully close under all service conditions within 30 seconds of actuation. Information about the closing time of the valves and their operating characteristics should be available on board and the closing time should be verifiable and reproducible. Such valves should close smoothly.

The requirements specify that the ESD system may be activated manually from at least two locations, including the cargo control station or room, if installed, or automatically via the melt plugs[5] in case of fire at the liquid or vapour domes of the cargo tanks or at the manifolds.

Many types of valve actuators require hydraulic or pneumatic pressure to operate in closing as well as opening directions. The requirement for the ESD valves to fail-closed on loss of power (which means 'motive power' in this context) is a safeguard to ensure that the valves will close in the event of loss of pressure in valve remote control systems, for example. The actual arrangement will depend on the specific type of actuator but, without such provision, the valves could stay open even though they received a 'close' signal from the ESD system or are in blackout conditions. The requirement for local manual operation is a further safeguard to ensure that the valve can be closed in the event of malfunction of the actuator itself. This topic is further discussed in Part 2.

The requirement for the ESD valves to close within 30 seconds sets an upper limit to the ESD valve closure time, which also cross-refers to the high level shutdown requirements elsewhere in the IGC (see sections 13.3.1 & 18.8.2). The requirement for smooth closure and information about closure times is in recognition that unless the ship and shore systems are linked, the ship's ESD valves may close against the flow from shore during loading and create a surge pressure. This is addressed in 13.3.1.

Equipment to be stopped by the ESD system

5.6.1.3	• Cargo pumps and compressors should be arranged to shutdown automatically if the emergency shutdown valves required by 5.6.1.1 and .2 are closed by the emergency shutdown system required by 5.6.4.

If the ESD valves described above are activated, the flow of cargo must also be stopped by tripping all cargo pumps and compressors in operation. During cargo transfer in port this means the ESD valves close and any cargo pumps or compressors are also stopped if they are transferring cargo between ship and shore or within the ship (eg reliquefaction). At sea, ESD activation again closes the ESD valves and stops the internal flow of cargo within the ship (eg reliquefaction, cargo re-heating, cargo mixing etc). Note: for some 'low pressure' ships, the only valves aboard that close on ESD are at the manifolds, so the only result of activating an ESD at sea may be that the cargo pumps and compressors stop because the manifold valves are closed already.

The reference to 'cargo pumps' includes all pumps that transfer liquid cargo, including 'primary pumps' (for example, deepwell pumps and submerged pumps), 'spray pumps', 'booster pumps', etc. Likewise the reference to (cargo) 'compressors' includes all machines transferring cargo vapour.

[5] Also known as thermal fuses, fusible plugs etc

When applying the IGC Code to LNG carriers, the requirements for gas fuel compressors to stop on ESD can require some further consideration. This is in part due to an ambiguity in the requirements for these systems which state:

16.4.1	• All equipment (heaters, compressors, filters, etc.) for making up the gas for its use as fuel and related storage tanks should be located in the cargo area in accordance with 3.1.5.4. • If the equipment is in a enclosed space, the space should be ventilated according to section 12.1 of the Code and be equipped with a fire-extinguishing system according to section 11.5 and with a gas detection system according to section 13.6, as applicable.
16.4.2	• The compressors should be capable of being remotely stopped from a position which is always and easily accessible, and also from the engine-room. • In addition, the compressors should be capable of automatically stopping when the suction pressure reaches a certain value depending on the set pressure of the vacuum relief valves of the cargo tanks. The automatic shutdown device of the compressors should have a manual resetting. • Volumetric compressors should be fitted with pressure relief valves discharging into the suction line of the compressor. The size of the pressure relief valves should be determined in such a way that, with the delivery valve kept closed, the maximum pressure does not exceed by more than 10% the maximum working pressure. The requirements of 5.6.1.3 apply to these compressors.

The ambiguity centres around the last sentence, which can be taken as requiring all gas fuel compressors to stop on an ESD signal or only those that are 'volumetric compressors'.

SIGTTO recommends that designers of ESD systems for LNG carriers either include the gas fuel compressors in the ESD system or fit additional safeguards as outlined in Part 2, Section 2.3 of this document. In deciding between these options designers should consider that, if the gas fuel compressors stop on ESD activation, the possibility exists of a 'blackout' if the alternative fuel systems required by 16.5.4 & 16.5.5 fail to operate correctly. It should also be noted that the loss of gas-burning capability makes it more difficult to control cargo tank pressures on those LNG carriers with this system. Similar considerations apply for LNG carriers with GCUs that require compressors to be running before they can operate.

The requirement for gas fuel compressors to trip on low cargo tank pressure is a reference to vacuum protection, which is already a requirement under 8.4.2.

Master gas fuel valve

16.3.7	• A master gas fuel valve that can be closed from within the machinery space should be provided within the cargo area. • The valve should be arranged to close automatically if leakage of gas is detected, or loss of ventilation for the duct or casing or loss of pressurization of the double-wall gas piping occurs.

The primary purpose of a master gas fuel valve is to close off the supply of gas to the relevant machinery space for safety and operational purposes. This valve is not required to be closed by the cargo emergency shutdown system.

Although there is no IGC Code requirement for the master gas fuel valve to fail-closed on loss of actuating power, in view of the valve's importance SIGTTO recommend that the valve actuator is designed to automatically close under failure mode conditions.

Other initiators of cargo system shutdown

In the IGC Code a number of other requirements make direct or indirect reference to the ESD system. These include:

Chapter 13 – 13.3 Overflow control

13.3.1	• Except as provided in 13.3.2, each cargo tank should be fitted with a high liquid level alarm operating independently of other liquid level indicators and giving an audible and visual warning when activated. • Another sensor operating independently of the high liquid level alarm should automatically actuate a shutoff valve in a manner which will both avoid excessive liquid pressure in the loading line and prevent the tank from becoming liquid full. The emergency shutdown valve referred to in 5.6.1 & 5.6.3 may be used for this purpose. If another valve is used for this purpose, the same information as referred to in 5.6.4 should be available on board. • During loading, whenever the use of these valves may possibly create a potential excess pressure surge in the loading system, the Administration and the port state authority may agree to alternative arrangements such as limiting the loading rate, etc

Note: 13.3.2 exempts some small pressure systems, with tanks below 200 m^3 capacity or those that can withstand surge pressures, from these requirements.

The Code permits a number of options for the high level shutoff valve and, although the emergency shutdown valve at the cargo tank or at the manifolds may be the usual choice, another separate valve could be designated for this purpose instead.

This requirement is clarified further in Chapter 18 as follows:

Chapter 18 – 18.8. Cargo transfer operations

18.8.2	The closing time of the valve referred to in 13.3.1 (ie time from shutdown signal to complete valve closure) should not be greater than: $3600 \times U \div LR$ [seconds], where U = ullage volume at operating signal level [m^3] LR = maximum loading rate agreed between ship and shore facility [m^3/h] The loading rate should be adjusted to limit surge pressure on valve closure to an acceptable level taking into account the loading hose or arm, the ship and the shore piping systems where relevant.

The purpose of the 'overfill protection system' is to prevent damage to the cargo tank in case it is over-filled and to prevent the potential release of liquid cargo from the vent mast. The valve closed by this overfill protection sensor may be at the cargo tank or at the manifold. However, the IGC Code also recognises that if these valves are fitted on the individual cargo tanks, the closure of the final valve is the same as closure of the manifold as far as the shore system is concerned. In other words, the valves are closed against the flow, which is likely to create a surge pressure that could be unacceptably high and rupture cargo hoses or arms. This is addressed by relating the loading rate to the valve closure time. *Alternatively this hazard is obviated by the arrangement recommended by SIGTTO, ie namely a linked ship-shore shutdown system.*

Chapter 8 – 8.4 Vacuum protection systems

8.4.2	Cargo tanks designed to withstand a maximum external pressure differential not exceeding 0.25 bar, or tanks which cannot withstand the maximum external pressure differential that can be attained at maximum discharge rates with no vapour return into the cargo tanks, or by operation of a cargo refrigeration system, or by sending boil-off vapour to the machinery spaces, should be fitted with:
8.4.2.1	two independent pressure switches to sequentially alarm and subsequently stop all suction of cargo liquid or vapour from the cargo tank, and refrigeration equipment if fitted, by suitable means at a pressure sufficiently below the maximum external designed pressure differential of the cargo tank; or

The clear intent of the Code here is to prevent potential damage to the cargo tank if liquid or vapour withdrawal reduces cargo tank pressure to the extent that tanks could be damaged. While the requirement is for an alarm followed by tripping of the devices causing the suction, the system is sometimes designed so that the second stage alarm causes an ESD trip. A consequence of this arrangement is that a low pressure signal from one tank can affect other tanks and systems.

Chapter 13 – 13.4 Pressure gauges

13.4.1	The vapour space of each cargo tank should be provided with a pressure gauge which should incorporate an indicator in the control position required by 13.1.3. In addition, a high-pressure alarm and, if vacuum protection is required, a low-pressure alarm, should be provided on the navigating bridge. Maximum and minimum allowable pressures should be marked on the indicators. The alarms should be activated before the set pressures are reached. For cargo tank fitted with pressure relief valves, which can be set at more than one set pressure in accordance with 8.2.6, high-pressure alarms should be provided for each set pressure.

This requirement is to draw the attention of ship's staff to situations when cargo tank pressures are approaching maximum or minimum limits. The navigating bridge is specified for the alarms because this is always manned when the ship is at sea.

In many cases the designers link these alarms as initiators to the ESD system, and include, for example, trips of the inert gas plant aboard being used to gas-free the cargo tank where the cargo tank pressure reaches the high pressure alarm. However, caution should be exercised if high or low pressure alarms are used in this way as tripping all cargo equipment, whatever the circumstances, could be undesirable.

Chapter 3 – 3.6 Airlocks

3.6.4	In ships carrying flammable products, electrical equipment which is not of the certified-safe type in spaces protected by air locks should be de-energized upon loss of overpressure in the space (see also 10.2.5.4). Electrical equipment which is not of the certified safe type for manoeuvring, anchoring and mooring equipment as well as the emergency fire pumps should not be located in spaces to be protected by airlocks.

It is common on many ships to use the ESD signal to de-energize the electrical supply to the cargo system, thereby closing the fail-closed valves and stopping any pumps or compressors that are running. For the same reason, loss of over-pressure in the air lock can also de-energize the whole cargo system and cause an ESD trip. This method of tripping groups of cargo machinery is frequently seen in ships designed to handle multiple grades, as it would be impractical to trip cargo machinery via their individual control circuits.

Summary

As explained above, the 1993 IGC Code requirements for the ESD system can be rather confusing.

It is very important that ship's staff are provided with a clear description of the system onboard, explaining how it is designed and the relationship between its inputs and outputs.

This is even more crucial in cases where the system is operated by a programmable logic controller, where the inputs cannot be traced in the same way that is possible with connections to an electro-mechanical control system.

Appendix B ESD Processing

In older vessels, the ESD system logic was effectively hard-wired but the next step was to use a programmable logic controller (PLC), in a similar manner to the offshore industry. More recently, ESD logic functions on some vessels have been incorporated into the ship's integrated automation system. The latter offers certain advantages in terms of flexibility but, if this route is followed, the designer must ensure that the principles of adequate redundancy, robust security and system locking are as good or better than that described here for a system based on PLCs.

Inputs to the ESD system are processed and outputs triggered according to the logic implemented. The processing element is considered in terms of the logic solver, its wiring and connections, power supply and user interface.

Logic solver

The ESD system should include a logic solving element that detects the status of input signals, processes the data and initiates necessary actions. This will typically comprise a programmable safety controller, or equivalent, and associated equipment for input and output signal conditioning.

It is recommended that programmable electronic equipment and all associated input and output devices is type approved by an IACS member Classification Society to ensure their suitability for the marine environment.

ESD logic solvers should be of inherently 'fail-safe' design such that an ESD is initiated in the event of likely equipment failures.

Although SIGTTO does not recommend a particular safety integrity level (SIL) for ESD functions, it is recommended that programmable electronic equipment, including its operating system and configuration software, should be proven for use in safety applications. Access to the system should be restricted so that software changes can only be made by suitably authorised persons in accordance with Appendix C. The system should be arranged so that there is no access to the configuration when the system is in normal use.

The ESD system should provide volt free contacts, or similar simple output types, to initiate alarms for ESD activation and ESD system fault at the cargo control station.

Considering the importance of the ESD system it is imperative that the manufacturer is instructed to provide a comprehensive fault-finding guide for the use of the crew to enable them to undertake logical fault finding in the event of a malfunction of the system.

Power supply

The ESD system should normally be supplied from the main source of electrical power. The incoming main power supply should be monitored and an alarm initiated at the cargo control station in case of failure.

The ESD system should be supplied automatically from a standby source of electrical power in the event that the main power supply to the system fails. This may be from the emergency source of power or a dedicated back-up supply. The incoming back-up power supply should be monitored and an alarm initiated at the cargo control station in case of failure.

Appendix C Testing of Linked ESD Systems for Gas Carriers

Introduction

Testing should be carried out before installation (factory acceptance testing), after commissioning (dock and gas trials), before each cargo loading/discharge and at each dry-docking. This should apply to both ship and shore systems.

Testing should be both comprehensive and systematic to demonstrate compliance with design objectives. Required and actual test results should be recorded and copies provided to all involved parties for reference. In service testing should be recorded and the cause of any problems noted.

It should be recognised that programmable electronic equipment is inherently complex and that functional testing in no way guarantees that the system is free from defect. However, the use of suitably certified equipment and the observance of quality management during design should mitigate this risk to a reasonably practicable level.

Factory Acceptance Testing

Once the basic design of hardware and software has been finalised, the system should be tested in the presence of the customers' representatives, typically the shipyard and prospective owner, and the recognised organisation responsible for issuing the Certificate of Fitness on behalf of the Administration.

The purpose of acceptance testing is to confirm that the equipment has been constructed and assembled to an acceptable standard and that the basic functionality meets the design intent. Testing should be carried out to a formal schedule based on the approved documentation, which should be made available for review in advance.

It is likely that only the processing elements of the ESD system (logic solver, etc) will be available for acceptance testing at the supplier's works. Therefore, input and output checks should use appropriate simulation techniques to verify that the system responds correctly.

Testing requirements should be agreed in advance and incorporated into the test schedule.

Commissioning Tests

Once the system is installed onboard, it should be tested by the supplier to demonstrate that all connections have been properly made and the system as a whole is functioning correctly.

On the basis that the system should have been tested at the supplier's works, the commissioning tests will focus on checking of loops to confirm that input sensors, push buttons, etc. are functioning correctly. Pressure switches and other such input devices should be adjusted and checked using calibrated test equipment. Similarly, the operation of ESD valves and other outputs should be checked prior to gas trials. These tests should be confirmed by the yard and the prospective owner. It is recommended that the system is tested in the presence of a Classification Society surveyor at the first loading.

In the case of overfill protection sensors, the methods of test will depend on the type of sensor. The supplier's recommendations for testing and calibration of sensors in dry-dock should be followed. For example, it is accepted practice to test capacitance type probes for LNG applications using a manufacturer's approved test fluid.

Gas Trials

The system should be tested on gas trials in the presence of the customers' representatives, typically the shipyard and prospective owner, and the recognised organisation responsible for issuing the Certificate of Fitness on behalf of the Administration. This test constitutes the final acceptance of the ESD system prior to delivery, so all pending matters should be resolved at this time.

The design and installation should already be verified by virtue of factory acceptance and commissioning tests, so it remains to validate the overall system by proving that it can stop liquid and vapour flows between ship and shore within the requirements of the IGC Code. This should be achieved by initiating an ESD and confirming that the manifold valves close within 30 seconds, and that all consequential trip and signalling actions occur as intended by the system's design.

It should be noted that if the gas trial has been carried out at an export terminal, the small quantities of liquefied gas typically loaded for trials purposes will be insufficient for testing tank overfill protection. Such tests may have to be deferred until the first cargo loading. If the sensor height is fixed then it will be necessary to fill the tank above the normal filling limit to prove that it is functioning properly in cold conditions, as described below.

Any remedial work carried out after gas trials should be strictly limited and verified as complete by all parties so that the Certificate of Fitness can be issued at the earliest practicable opportunity after delivery to the owner.

Testing of Cargo High Level Sensors

This paragraph covers the testing of the type of independent high level sensor described in the example of cargo tank overflow protection in Section 3 of Part 2.

The upper (ESD-1 level) independent sensor should be tested on first cargo and following significant maintenance. Some operators are reluctant to overfill the tank in order to test this sensor and have specified that the independent sensors should be removable in service. However, while this might allow in-service maintenance, testing then relies on simulation and would not necessarily detect a punctured float, for example. Sequentially filling each tank to the ESD-1 level, using one pump at a time, positively tests the complete overfill protection system in its normal operating mode. Provided that the test is planned in a logical manner and carefully controlled, it can be executed smoothly and safely. However, it should only be attempted with the manifold valves closed and ship/shore link inhibited or disconnected.

After the test has been completed, and before sailing, the level in the final tank should be lowered such that the approved filling limit is not exceeded.

Routine Testing Prior to Cargo Operations

The IGC Code requires that cargo emergency shutdown and alarms systems involved in cargo transfer should be tested and checked before cargo handling operations begin.

The aim of this testing is to establish that the ESD valves will be closed automatically on ESD initiation within the required 30 seconds. It is not usually necessary to check each and every input to the system before every cargo transfer. It is, however, recommended that all inputs and outputs are tested over time to an appropriate schedule. The testing should not itself compromise the integrity of the system.

Certain designs of ESD valves do not have a positive connection between the actuator and the valve and it is possible for the valve to remain open while the actuator is in the 'shut' position[6]. If valves of this type are fitted it is essential that a test procedure is developed to ensure that the valve provides a positive shut-off.

It is recognised that it is not practical to test certain sensors while the ship is in service. However, loops should be checked by appropriate simulation methods, such as disconnecting the sensor and observing that an ESD is initiated by the open circuit condition. The system should be fully reinstated after any such checks. On systems where the high level alarm is combined with a float level gauge, it may be possible to lift the float switch by manually raising the level gauge.

It is not uncommon for fibre-optic links to suffer from signal attenuation problems as a result of small impurities/particles such as salt etc. getting lodged in the connectors, resulting in an unreliable link. As part of the routine testing prior to arrival, the cleaning of these connectors as per manufacturer's guidelines should be considered 'best practice'.

Fibre-optic systems are usually provided with a dummy plug, or simulator, to enable testing of the optical circuits before arrival. Similarly, a test plug is provided with the SIGTTO link for pre-arrival testing of the hazardous area side of the electrical circuit. This procedure should be carried for both the ship and shore equipment.

Pre-arrival checks should include physical inspection of the ship/shore electric or fibre-optic cables and/or pneumatic hoses.

[6] See MAIB report No. 10/2007 "Major LPG Leak from Gas Carrier *Ennerdale*"

Post-arrival testing should include a function test of the link after connection but before commencement of cargo operations. This involves opening the manifold valves and proving they close by tripping the link. It is good practice to demonstrate proper valve movement in the cold condition by manipulating the valve at the end of arm cooldown. It is not essential to combine this cold valve test with a second ESD link test.

Dry-dockings

Dry-dockings provide an opportunity to gain access to tanks, overhaul valves and generally maintain the ESD system in good working order.

Level measurement sensors should be checked and recalibrated at this time by competent persons in accordance with the supplier's instructions and, if appropriate, the requirements of fiscal authorities. At the same time, the opportunity should be taken to inspect and recalibrate any fixed independent high level alarm sensors in the tank.

All opened and overhauled equipment should be fully checked before being put back into service.

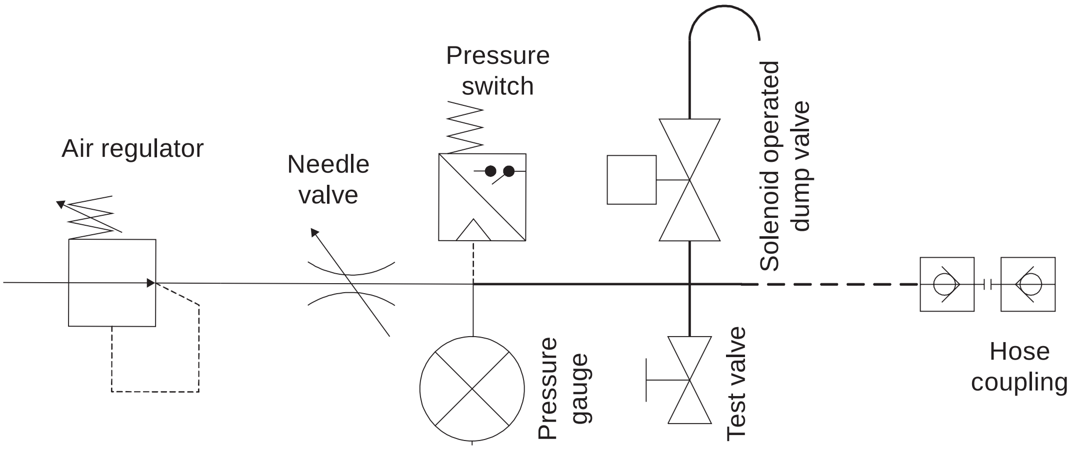
Modifications to logic and software should be made only with the consent of authorised persons and carried out in accordance with Safety Management System procedures for change management and version control, by a suitably qualified technician.

Where any loop has been disconnected or modified, full loop checking should be carried out to ensure that the system has been properly re-commissioned.

A function test should be carried out on completion of work to confirm that the system is working correctly prior to departure. Where agreed by the Administration, certain checks may be deferred until the first laden passage to confirm satisfactory operation under cold conditions.

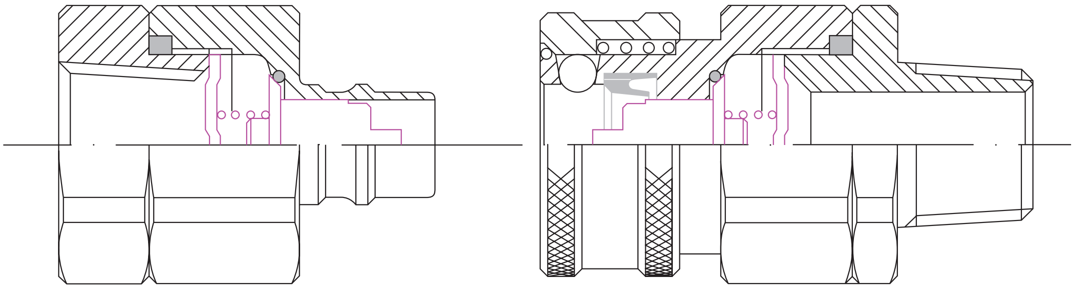
Appendix D Pneumatic ESD Links

In the majority of terminals, pneumatic links are only now provided as a backup in the event of failure of the main optical fibre or electrical link. A typical system is shown below:



Operating pressures vary between two and seven bar, the air being supplied from shore at some installations and from the ship at others. The normal set point should be about 80% of the supply pressure to ensure rapid tripping, commonly used is 2.7 barg supply pressure and 2.4 barg tripping pressure.

At least two types of connector are in use but the most common is the standard ½" MIL-C-51234 quick connector, available from the *Snap-tite 'H' series,* or its Nitta-Moore equivalent. Both manufacturers using the same ordering code. A nipple is fitted to the ship's fixed piping with the coupler fitted to the hose. The normal arrangement is for couplers at both ends of the hose so that it can be completely disconnected from the terminal's nipple when not in use.



SVHN8–8F
½" Nipple + ½" NPT female

SVHC8–8M
½" Coupler + ½" NPT male

Body Material	Valve or Plain	Series	Type	Size	-	End Fitting
S = stainless steel 316	V = valve	"H"	N = nipple	8 = ½"	-	8F = 1/2"NPT female
			C = coupler			8M = 1/2"NPT male

The first part of the number is important to ensure compatibility, the second part of the number describing the end fitting can be varied to suit the actual installation. The connectors illustrated are self-sealing to prevent dirt and seawater entering the system, but will still allow air to be dumped in the event of hose rupture. This is normally adequate although in some installations, a plain nipple is used so that air will also release in the event of manual disconnection.

Arun, Bontang and Yung An are all known to specify Snap-tite connectors, while Japanese terminals normally quote Nitta-Moore. However, either manufacturer's product should be suitable.

One project has nipple and coupler in opposite configuration and three terminals in Japan, originally receiving LNG from Bintulu, are known to use a different connector made by Stäubli of Pfäffikon, Switzerland.

Appendix E Pyle-National Electric Link Connector

The original cable used for the Pyle-National control connector comprised sixteen screened pairs connected as follows:

Pyle-National Ref AF-B1716-621SL-AG (receptacle)

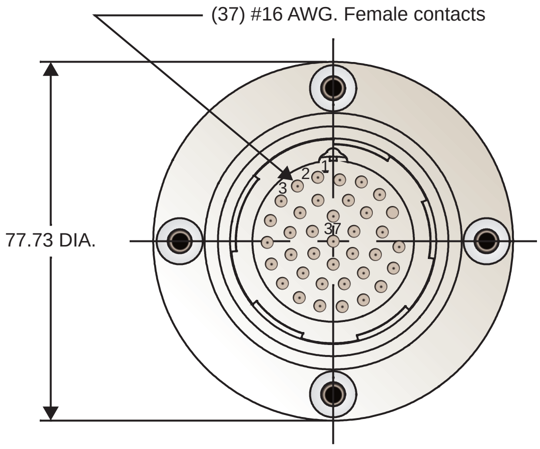
#	Pins	'Standard'	Comment
1	01/02	Sound powered telephone	Few terminals currently use this
2	03/04	Ex 'ia' telephone	Dual LPG/LNG jetties
3	05/06	Interphone or Hotline	Uses either Iwatsu DC shift call or 48VAC signalling
4	07/08	Public telephone #1	Standard 600 ohm off hook/6000 ohm on hook 48VAC/80VAC ring type
5	09/10	Public telephone #2	Standard 600 ohm off hook/6000 ohm on hook 48VAC/80VAC ring type
6	11/12	Not connected	4~20mA signal (vapour pressure transmitter). Used by 2 older US terminals
7	13/14	ESD-1 shore (export) → ship	Volt-free contact – closed when healthy
8	15/16	ESD-1 ship → shore	Volt-free contact – closed when healthy
9	17/18	Continuity loop linked on ship	Confirms to shore link connected
10	19/20	Spare	Some terminals use for continuity check
11	21/22	Not normally used	Receiving tank level high signal from shore. Not normally used
12	23/24	Not currently used	ESD shore - ship
13	25/26	Not currently used	Loading arms 1st stage
14	27/28	Not currently used	Loading arms 2nd stage
15	29/30	+24V 35mA ship/shore test circuit	Safe power for shore circuit test
16	31/32	MLM data connection	ground
			Rx shore-ship
	33/34	MLM data connection	Tx ship-shore
			Ground
	35/36	+24V 35mA ship/shore test circuit	Safe power for ship circuit test
	37	Not connected	

History of the System and Current Developments

Vapour return during loading in Algeria for the early dedicated ships was effected by a compressor installed ashore, controlled by the ship's vapour header pressure by means of 4~20mA signal passed via pair #6. On these ships, contacts for the 'continuity' signals, #9 (discharging) or #10 (loading), were closed by means of a shipboard selector switch, which provided confirmation of the ship's switch status to the shore control room. In the 'discharging' position, this switch also set up the ship's system to monitor signals #11, 12, 13 and 14 – these signals only applying to the original receiving terminals in France and later Belgium and their dedicated ships.

A second, additional, Pyle-National cable is installed at the above terminals. The receptacle is a 'GD' series 4-pin, 60A power connector, believed to be for grounding. As such its use is not recommended by SIGTTO.

With one notable exception, all later LNG terminals that have adopted the Pyle-National ship/shore link have **loosely** followed this basic system, albeit with some modifications, particularly with regard to telephony. In general, the first five pairs (pins 1 to 10) have been retained as telephony channels but individual telephone instruments and their allocation to these channels has been varied to suit the particular project.



To make full use of the available pins, a number of terminals have increased the number of cores in the connecting cable to 18 pairs, generally using pins 29 to 36 for additional services such as mooring loading monitoring or environmental data.

Fortunately, so far as ESD-1 is concerned, there is little variation and these terminals have consistently used #8 for the ship → shore ESD-1 signal. Although #7 was originally intended for the shore → ship ESD-1 signal at only LNG export terminals, practically every new terminal, import and export, has standardised on #7 for the shore → ship ESD-1 signal. Signal #12 has been retained for this purpose at the French and Belgian terminals already mentioned, while a couple of terminals and a number of ships have the flexibility to use either #7 or #12 for this purpose.

As mentioned, one LNG import terminal has adopted a completely different connection arrangement and is therefore incompatible with every other system.

SIGTTO Recommendations

To avoid over-complication and improve reliability, it is recommended that all shore initiation signals, including receiving tank high level and loading arm over-extension, are processed by the shore ESD system and passed to the ship as a single ESD-1 trip signal, not as individual signals.

For new terminals, the vapour pressure signal (#6), the 'continuity' signals (#9 & 10), the receiving tank high level (#11) and loading arm over-extension (#13 & 14) are almost certainly unnecessary.

Pin connections for ship/shore ESD-1 should be standardised for all new projects as follows:

#	Pins	Standard function	Comment
7	13/14	ESD-1 shore → ship	Shore presents IS-output contact – closed when healthy
8	15/16	ESD-1 ship → shore	Ship presents IS-output contact – closed when healthy

As the cable and receptacles are in the hazardous area, the contact status should be detected by a suitable intrinsically-safe device, such as a switch/proximity detector interface unit to relay the signal to equipment in the safe area.

Existing LNG import terminals that use #12 (pins 23/24) to pass the ESD-1 signal to the ship should consider the practicality of duplicating this signal via #7 for compatibility with non-dedicated ships.

All ship/shore links should pass ESD-1 signals in the shore → ship as well as the ship → shore direction.

As the primary purpose of the linked system is to coordinate ship and shore ESD actions, no attempt will be made in this document to cover in detail the secondary uses, such as telephone links, or tertiary uses such as the transfer of mooring load or environmental data. SIGTTO recommendations will, therefore, be limited to the following:

At least one telephone connection should be provided to enable communications between the ship and shore control rooms. This should be connected via #3 (pins 5/6) and preferably have private line mode (also called 'lift to ring', 'auto-dial' or 'hotdial').

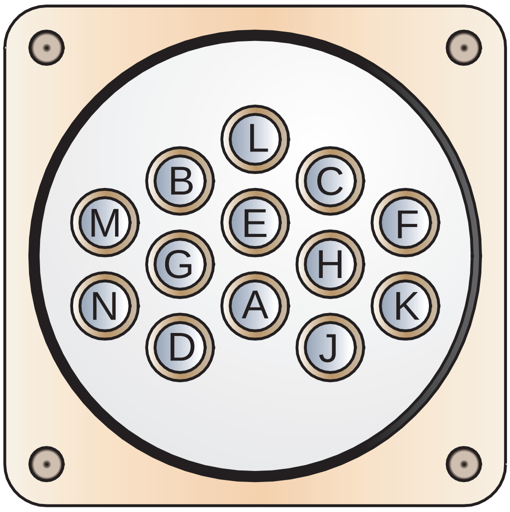
Pair #4 and #5 should be reserved for connecting other telephones.

Although the ESD signals are protected by zener barriers to limit the voltage and current to a safe level, telephone systems operating at 48v DC and 80v AC ring cannot be protected in this way. In some terminals, the risk of an incendive spark has been lessened by using a relay operated via the 'continuity' circuit to isolate the telephone lines while the cable is being connected. However, this would not remove the risk due, say, to the cable being cut and shorting on the jetty. It is recommended that all terminals review the system in place to protect all ship/shore circuits, including telephones.

Appendix F ITT-Cannon Telephone Connector

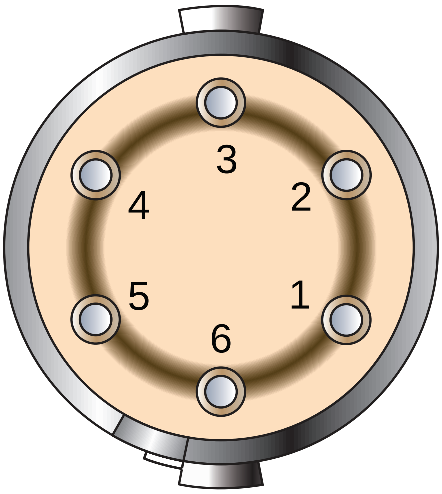
The ship's connection is an ITT-Cannon MR02-20-11 SF11 1 receptacle. The table shows the standard configuration, although not all terminals have all three telephones.

Pins	'Standard' Connection
A	Public Telephone
B	
C	
D	Hotline Telephone
E	
F	
G	
H	Plant (PABX) Telephone
J	
K	
L	



Appendix G Miyaki Denki Electric Link Connector

These connectors are manufactured by Miyaki Denki, Kameoka, Japan. In 2003, the connectors were redesigned to achieve ATEX Compliant CENELEC Eex 'd' certification and the current designation is 21-EC-PT. The receptacle incorporates a switch to prevent plug insertion or removal with the receptacle 'live'.



Shore connector (male)

Any new projects adopting the system should follow the pin arrangement shown the table, which is compatible with the terminals in Korea and Qatar where use of the system has survived. Under this standard, only two connectors are necessary – one for ESD-1, one for telephones.

It is recommended that existing terminals using this link, should arrange for passing ESD-1 signals in both directions (not just in the shore → ship direction) so that the appropriate valves close on the shore side.

As supplied, pin 6 of receptacles are normally connected to earth (ground). This link should be removed.

<table>
<tr><th>ESD-1 Connection</th><th>Pin</th><th>Telephone Connection</th></tr>
<tr><td rowspan="2">ESD-1 ship → shore</td><td>1</td><td rowspan="2">InterPhone or Hotline Telephone</td></tr>
<tr><td>2</td></tr>
<tr><td rowspan="2">ESD-1 shore → ship</td><td>3</td><td rowspan="2">PABX Telephone</td></tr>
<tr><td>4</td></tr>
<tr><td rowspan="2"></td><td>5</td><td rowspan="2">Public Telephone</td></tr>
<tr><td>6</td></tr>
</table>

For information, the following table shows the connections of the three Miyaki connectors that are still in active use at some Japanese gas terminals.

<table>
<tr><th>ESD-1 Connection</th><th>Pin</th><th>Telephone Connection</th><th>Interphone Connection</th></tr>
<tr><td rowspan="2">ESD-1 ship → shore</td><td>1</td><td rowspan="2">Public Telephone</td><td>L1</td></tr>
<tr><td>2</td><td>L2</td></tr>
<tr><td></td><td>3</td><td rowspan="2">PABX (internal) Telephone</td><td>-</td></tr>
<tr><td rowspan="2">ESD-1 shore → ship</td><td>4</td><td>+</td></tr>
<tr><td>5</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td></td><td>6</td></tr>
</table>

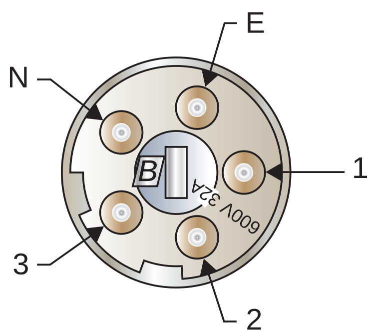
Appendix H SIGTTO Electric Link System

The standard shore configuration comprises:

- A terminal assembly for installing in the in the terminal's control room, *connected to*
- a jetty assembly, *connected to*
- a ship/shore cable fitted with a free plug.

The standard ship configuration comprises:

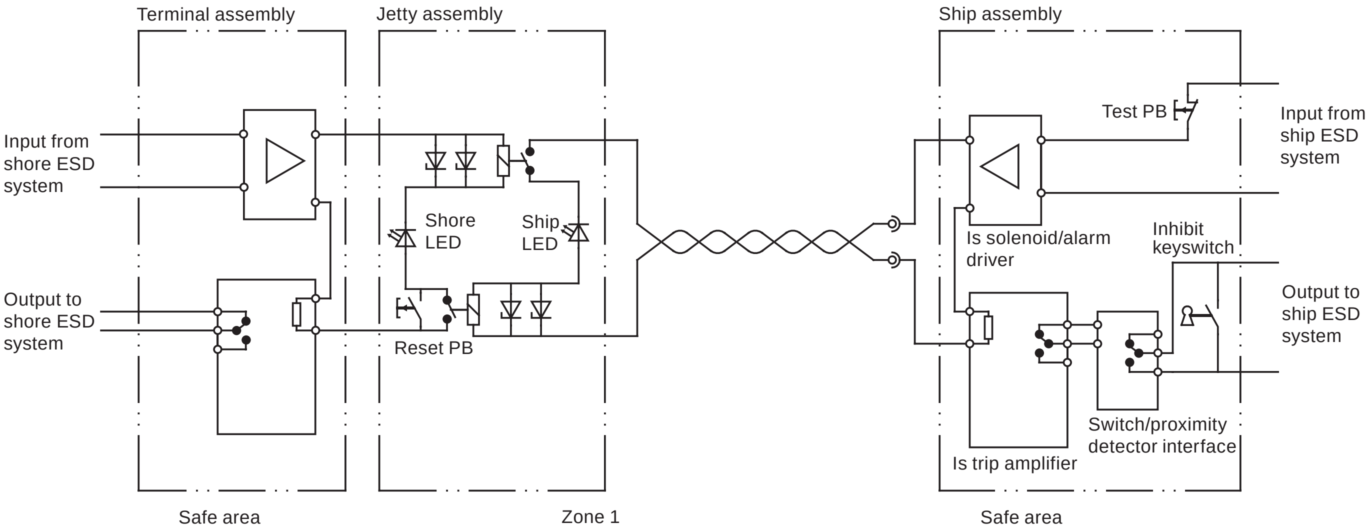
- A ship assembly for installing in the in the ship's control room, *connected to*
- international fixed socket assemblies for installing in the ship's manifold area, port and starboard.



The ship/shore cable should be twisted pair with blue coloured sheath without armour or screen (to avoid the hazard of a potentially incendive spark should the insulating sheath be cut by an earthed object on the jetty). The pin designations are:

1	+	Intrinsically safe circuit, nominal 24v dc, 20mA
2	-	Intrinsically safe circuit, nominal 24v dc, 20mA
3	+	Spare
N	-	Spare
E		Not connected

Alternatively, two pairs may be connected in parallel using pins 3 & N.



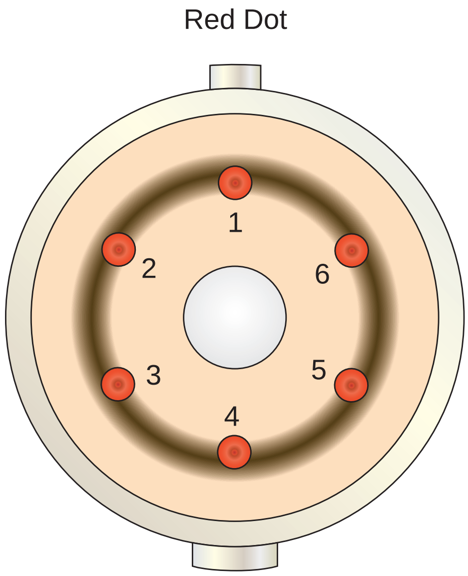
In the jetty assembly two relay loops are connected back-to-back, isolating the ship and terminal ESD systems from each other as shown. When the ship ESD system is healthy, an IS solenoid driver in the ship assembly is energised, making power available on the 'ship' side of the jetty assembly via the ship/shore cable. If the terminal ESD system is also healthy, the 'shore' side loop is similarly powered up and the system. Pressing the reset button in the jetty assembly will then energise the upper relay, closing its contact and energising the lower relay. The ship/shore link is then 'armed'. Breaking either ship or shore loops, either by breaking contacts or by physical disconnection, will cause both relays to drop out, ensuring a simultaneous linked trip.

The above diagram has been simplified for clarity. In the actual system, the terminal assembly has a separate reset pushbutton and indicators to show whether a trip was initiated by the shore or by the ship. There is also additional circuitry to allow connection of pendant units and to facilitate testing.

Appendix I Fibre-optic Link Connector

The standard configuration of the optical fibre ink is as shown in the tables. The diagram shows the allocation of fibres for the connector.

Core	Direction	Signal	
1	→	4-channel multiplex data	ship to shore
2	←		shore to ship
3	→	ESD-1 volt free contact	ship to shore
4	←		shore to ship
5	→	Spare/digital SSL	ship to shore
6	←	Spare/digital SSL	shore to ship



CH1	MLM modem signal 1200 baud
CH2	Hotline telephone – Iwatsu TS3 format only supported
CH3	Terminal public telephone audio signal
CH4	Terminal PABX (internal) telephone audio signal

A test plug is usually provided that has internal loops to return the ship-to-shore signals back to the relevant receiver. It is used in conjunction with the test button to prove the circuits, including the cables to each shipside or jetty connector. The test plug must not be left permanently connected.